Iron and Steel Engineer

Established 1907 as Proceedings of A. I. & S. E. E.

T. B. LITTLE, EDITOR

CONTENTS

Vol. XII. FEBRUARY, 1935 No. 2

Lightning Protection for Power Systems, by B. Van Ness, Jr., Electrical Engineer, and Edward Hansson, Transmission Engineer, Pennsylvania Water & Power Company, Baltimore, Md. 73

Discussion—Lightning Protection for Power Systems— Discussion presented by W. H. Burr, F. A. Allner, J. C. Reed, L. H. Fister, B. Van Ness, Jr., A. J. Standing, E. Hansson, H. H. Angel, E. L. Anderson, and H. D. Esterly 81

Electric Overhead Traveling Cranes, by R. J. Harry, General Manager, Alliance Machine Company, Alliance, Ohio 84

Crane Wheels, by J. C. Keel, Mechanical Engineer, Bethlehem Steel Company, Steelton, Pa. 87

Crane Safety, by R. F. Gale, Plant Engineer, The Midvale Company, Nicetown, Philadelphia, Pa. 87

Anti-Friction Bearings for Cranes, by A. J. Standing, Electrical Supt., Bethlehem Steel Company, Bethlehem, Pa. 88

Crane Control, by H. H. Angel, Electrical Dept., Bethlehem Steel Company, Sparrows Point, Md. 90

Crane Motors and Gears, by G. C. Pfeffer, Electrical Engineer, Florence Pipe Foundry & Machine Company, Florence, N. J. 91

Crane Control, by W. R. Yorkey, Engineer, The Electric Controller & Manufacturing Co., New York, N. Y. 91

Crane Wheels, by E. S. Sawtelle, Vice President, The Tool Steel Gear & Pinion Company, Cincinnati, Ohio 92

Maintenance Crane Bridges and Trolleys, by F. D. Egan, Electrical Superintendent, Bethlehem Steel Company, Lackawanna, N. Y. 92

Track Wheels—Rails—Bumpers, by J. A. Burg, Mechanical Engineer, Carnegie Steel Company, Homestead, Pa. 93

Crane Rails, by G. R. Carroll, Electrical Superintendent, Jones & Laughlin Steel Corporation, Aliquippa, Pa. 94

Bearings, Lubrication, Gears and Pinions, Shafting, by J. Farrington, Elec. Supt., Wheeling Steel Corp., Steubenville, Ohio 95

General Maintenance, by C. W. Upton, Maintenance Dept., Bethlehem Steel Company, Johnstown, Pa. 96

General Maintenance, by T. B. McElray, Supt. of Light & Power, Carnegie Steel Company, Youngstown, Ohio 97

General Maintenance, by A. W. Duncan, Electrical Supt., Weirton Steel Company, Weirton, W. Va. 98

General Discussion presented by H. W. Ball, Leroy Brooks, B. R. Shover, J. L. Young, W. E. Miller, G. R. Carroll, A. W. McAuly, R. J. Harry, J. Farrington, M. J. Conway, and W. A. Marshall 99

Bridges and Trolleys, by B. A. E. Rosenquist, Design Engineer, Carnegie Steel Company, Duquesne, Pa 102

Maintenance Problems on Old Cranes, by G. W. Baumgarten, Asst. Elec. Engr., Carnegie Steel Company, Duquesne, Pa. 102

Thermit Welding, by J. B. Tinnon, Manager of Sales, Metal & Thermit Corp., New York, N. Y. 104

Discussion—Thermit Welding—Discussion presented by C. Simera, L. F. Coffin, J. B. Tinnon, J. F. Gillespie, and C. O. Franklin 108

Items of Interest 110

A. I. & S. E. E. Iron and Steel Exposition II and III

Index to Advertisers IV

Published Monthly by

Association of Iron and Steel Electrical Engineers

BOARD OF DIRECTORS—1934-1935

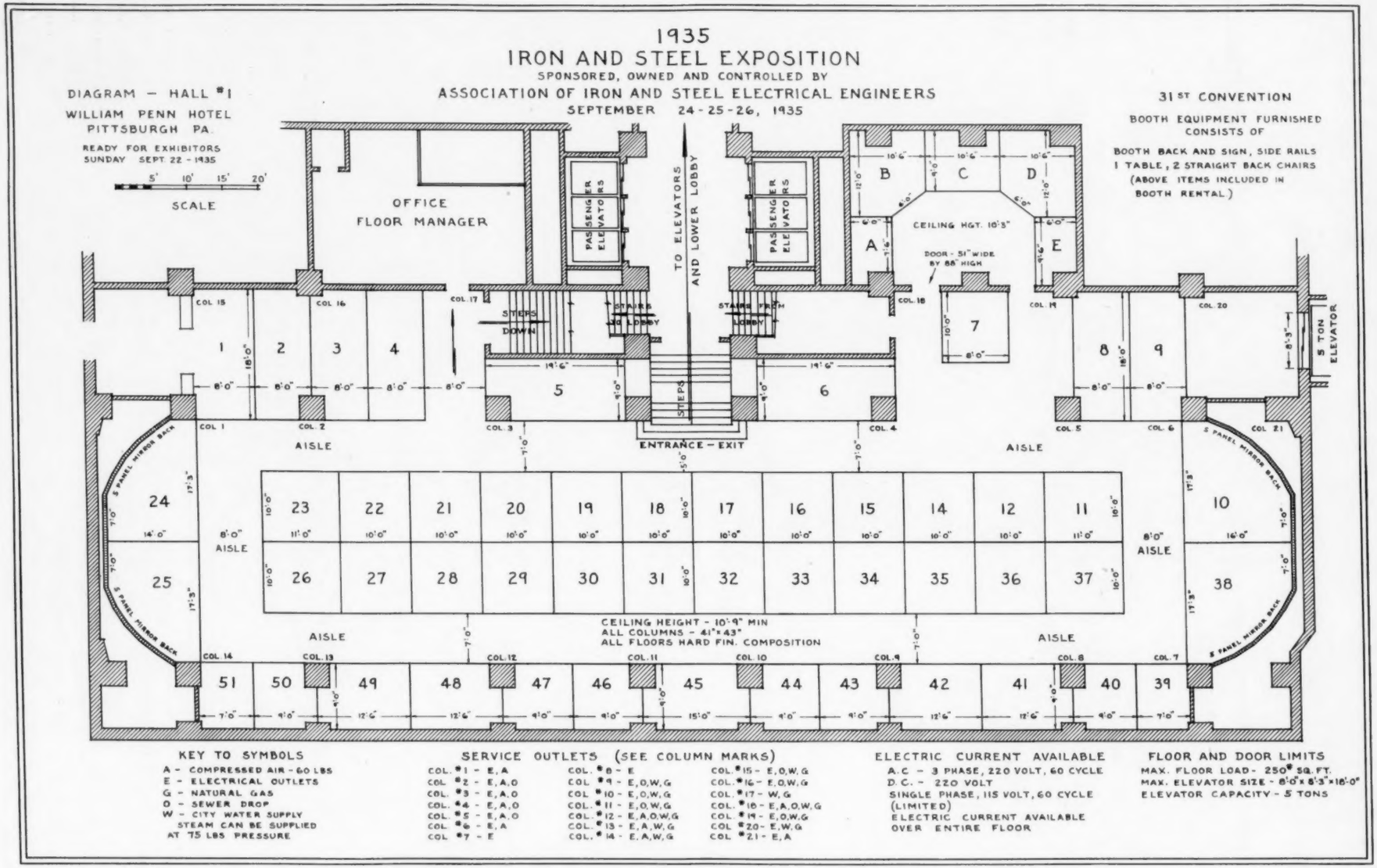
President, W. H. Burr, Mechanical and Electrical Superintendent, Lukens Steel Co., Coatesville, Pa.

1st Vice Pres., J. A. Clauss, Chief Engineer, Great Lakes Steel Corp., Ecorse, Mich.
2nd Vice Pres., G. R. Carroll, Elec. Supt., Jones & Laughlin Steel Corp., Aliquippa, Pa.
Director at Large, C. A. Thayer, Chief Engineer, Republic Steel Corp., Youngstown, Ohio.
Honorary Director, J. Farrington, Elec. Supt., Wheeling Steel Corp., Steubenville, Ohio.
Honorary Director, E. Friedlander, Pittsburgh, Pa.
Past President, W. E. Miller, Mech. and Elec. Supt., Bethlehem Steel Co., Johnstown, Pa.
Past President, J. D. Donovan, Mech. and Elec. Supt., Republic Steel Corp., Massillon, Ohio.
Treasurer, W. S. Hall, Chief Engineer, Illinois Steel Company, South Chicago, Ill.
Secretary, A. D. Adams, Asst. Supt., Spang Chalfant Company, Inc., Ambridge, Pa.
Director, C. A. Kral, Asst. General Manager, Wheeling Steel Corp., Steubenville, Ohio.
Director, C. C. Wales, Chief Engr., Otis Steel Co., Cleveland, Ohio.
Director, J. L. Miller, Asst. Chief Engr., Carnegie Steel Co., Youngstown, Ohio.
Director, L. F. Coffin, Supt. Mechanical Department, Bethlehem Steel Co., Sparrows Point, Md.
Director, K. E. Dinius, Chief Testing Engr., Illinois Steel Co., South Chicago, Ill.
Director, C. C. Pecu, Lubrication Engr., Bethlehem Steel Co., Lackawanna, N. Y.
Director, E. P. Winters, Power Engr., Sloss Sheffield Steel & Iron Co., Birmingham, Ala.
Director, E. F. Blank, Dir. of Safety and Welfare, Jones & Laughlin Steel Corp., Aliquippa, Pa.
Director, C. H. Hunt, Asst. to Pres., Weirton Steel Co., Weirton, W. Va.

Acting Managing Director, T. B. Little, Empire Building, Pittsburgh, Pa.

Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879.
Subscription Price $5.00 per Year. Single Copy $1.00.

IRON AND STEEL EXPOSITION, PITTSBURGH, PA., SEPTEMBER 24, 25, 26, 1935



KEY TO SYMBOLS

A - COMPRESSED AIR - 60 LBS
E - ELECTRICAL OUTLETS
G - NATURAL GAS
O - SEWER DROP
W - CITY WATER SUPPLY
STEAM CAN BE SUPPLIED AT 75 LBS PRESSURE

SERVICE OUTLETS (SEE COLUMN MARKS)

COL. #1 - E, A
COL. #2 - E, A, O
COL. #3 - E, A, O
COL. #4 - E, A, O
COL. #5 - E, A, O
COL. #6 - E, A
COL. #7 - E
COL. #8 - E
COL. #9 - E, O, W, G
COL. #10 - E, O, W, G
COL. #11 - E, O, W, G
COL. #12 - E, A, O, W, G
COL. #13 - E, A, W, G
COL. #14 - E, A, W, G
COL. #15 - E, O, W, G
COL. #16 - E, O, W, G
COL. #17 - W, G
COL. #18 - E, A, O, W, G
COL. #19 - E, O, W, G
COL. #20 - E, W, G
COL. #21 - E, A

ELECTRIC CURRENT AVAILABLE

A.C - 3 PHASE, 220 VOLT, 60 CYCLE
D.C. - 220 VOLT
SINGLE PHASE, 115 VOLT, 60 CYCLE (LIMITED)
ELECTRIC CURRENT AVAILABLE OVER ENTIRE FLOOR

FLOOR AND DOOR LIMITS

MAX. FLOOR LOAD - 250# SQ. FT.
MAX. ELEVATOR SIZE - 8'-0" x 8'-3" x 16'-0"
ELEVATOR CAPACITY - 5 TONS

THE IRON & STEEL EXPOSITION

SHOWN ON THE OPPOSITE PAGE IS THE FLOOR PLAN OF THE IRON AND STEEL EXPOSITION WHICH WILL BE HELD IN CONJUNCTION WITH THE A. I. & S. E. E. CONVENTION SEPTEMBER 24, 25 AND 26, 1935 AT THE WILLIAM PENN HOTEL IN PITTSBURGH, PA.

AS IN PREVIOUS YEARS THE EXPOSITION WILL BE ONE OF THE LEADING FEATURES OF THE CONVENTION. HERE THE MANUFACTURERS OF ELECTRICAL, MECHANICAL, COMBUSTION, WELDING, LUBRICATION, AND SAFETY EQUIPMENT WILL DISPLAY THEIR NEW AND STANDARD EQUIPMENT FOR INSPECTION BY THE ENGINEERS AND EXECUTIVES OF THE STEEL INDUSTRY ATTENDING THE CONVENTION.

PARTICULARLY IMPORTANT SHOULD BE THIS COMING EXPOSITION. WITH DEMANDS FOR CLOSER TOLERANCES BECOMING MORE EXACTING FROM THE CONSUMERS OF STEEL, AS WELL AS THE NECESSITY FOR THE INDUSTRY TO REPLACE OBSOLETE EQUIPMENT, THIS IRON AND STEEL EXPOSITION WILL PROVIDE THE IDEAL PLACE FOR THE EQUIPMENT MANUFACTURERS TO DEMONSTRATE THAT WITH THE INSTALLATION OF MACHINERY OF THE LATEST DESIGN THIS HIGH QUALITY DEMAND CAN BE SATISFIED.

WITH RESPECT TO SPACE RESERVATIONS FOR THE EXPOSITION, THE MANUFACTURERS ARE URGED TO MAKE THESE EARLY AS THE SPACE WILL BE ALLOTED IN THE ORDER IN WHICH THEY ARE RECEIVED.

FURTHER DETAILS ON BOTH THE EXPOSITION AND CONVENTION WILL APPEAR MONTHLY IN THE IRON AND STEEL ENGINEER.

INDEX TO ADVERTISERS

A

Alliance Machine Co. ..... Cover 1
Allis-Chalmers Manufacturing Co. 136
Aluminum Company of America 123

B

G. H. Bales 139
Bussmann Manufacturing Company 115

C

Carnegie Steel Company 144
Cleveland Crane & Engineering Co. 145
Crocker-Wheeler Electric Manufacturing Co. 138

E

The Electric Controller & Mfg. Co. 146

F

Farrel-Birmingham Company, Inc. 141

G

General Electric Company 121-Cover 4

H

Hyatt Roller Bearing Company 131

I

Independent Air Filter Company, Inc. 147
I-T-E Circuit Breaker Company ..... Cover 3

J

Jefferson Electric Company 127

L

Ladd Equipment Co. 139
Lewis Foundry & Machine Co. 120
Lincoln Electric Company 128

M

Mackintosh-Hemphill Company 126
The Martindale Electric Co. 143
McGraw Electric Company 115
McVey Hausman Co. 139
Mesta Machine Company 129
The Morgan Engineering Co. 133

N

National Carbon Company, Inc. 124-142
The New Departure Mfg. Company 119
New York & New Jersey Lubricant Co. 140
Norma-Hoffmann Bearings Corporation 125

O

The Ohio Carbon Company 141

P

Pennsylvania Transformer Company 143
Poole Foundry & Machine Co. 139

R

Reitz Sales Co. 139
Reliance Electric & Engineering Co. 135
Rockbestos Products Corporation 137

S

SKF Industries, Inc. 117
Stimple & Ward Co., Inc. 140
Surface Combustion Corporation 118

T

The Thompson Electric Co. 142
The Timken Roller Bearing Company 148
Tool Steel Gear & Pinion Co. 134
The Trumbull Electric Mfg. Co. 132

U

Union Carbide and Carbon Corporation 124-142

W

Wagner Electric Corporation 130
The Wellman Engineering Co. 122
Westinghouse Electric & Mfg. Co. ..... Cover 2

Lightning Protection For Power Systems

By B. VAN NESS, JR., Electrical Engineer, and EDWARD HANSSON, Transmission Engineer, Pennsylvania Water & Power Company, Baltimore, Md.

Paper presented before the Philadelphia District Section of the A. I. & S. E. E., February, 1934.

Introduction

Successful transmission of electric power requires a continuous supply of energy at the point of delivery, for in many industries an interruption of only a few seconds duration represents a serious loss. The most frequent cause of outage on open wire lines is grounds and short circuits from lightning. Lightning has always been a difficult problem to deal with as comparatively little is definitely known of its characteristics.

EDWARD HANSSON

B. VAN NESS, JR.

In contrast with most other systems, which had their initial generating stations close to the load centers, the Pennsylvania Water & Power Company began operation in 1910 as a generating and transmission company. All of its power was delivered in bulk, over high tension lines, and it became vitally interested in lightning protection from the start. Initially, lightning troubles had to be accepted as more or less unavoidable. However, as novel types of protective schemes were being developed, the company applied them to its system one after the other in an effort to improve the reliability of its service, drawing on the experiences of other organizations in this country and abroad. A number of its own experiences and research work with these schemes are referred to in this paper, even though some of them now are of only historical value.

Mechanism of the Lightning Stroke

In the early days a lightning cloud was considered as a huge condenser, charged to such a high voltage, that the air gap between the cloud and the earth broke down and there was an instantaneous discharge of the cloud. If this were true, a transmission line directly under, or in the vicinity of the cloud, would accumulate a charge of opposite polarity to that of the cloud. At the instant of discharge, this charge would be released and produce such a high voltage on the wires that the insulation would break down. Another theory, once accepted, was that the lightning discharge was oscillating and consequently the resulting surge on the line was believed to be of the nature of a high frequency oscillation[1]. For many years the general belief was that these were the cause of most lightning troubles on transmission lines. It was felt that direct hits were rare, and that they contained so much energy that it was hopeless to try to design a line that could withstand them.

The early studies of lightning were handicapped for lack of suitable measuring and recording tools. As larger blocks of power were transmitted longer distances, and as transmission lines became of increasing economical importance, an intensive study of the lightning problem began.

Methods were developed and steady progress was made. First, sphere gaps were used to try to arrive at the magnitude of the voltage produced on a line during a thunderstorm. Then, Mr. Peters of the Westinghouse Company conceived the idea of using the Lichtenberg figures for measuring transient voltages and developed the Klydonograph[2]. This instrument soon showed that lightning discharges were

1—Refer to Bibliography.

undirectional and that in every case the magnitude of the potential appearing on the wires was limited by the amount of insulation on the line. Shortly after the advent of the Klydonograph, Dr. Norinder modified the DuFour Cathode Ray Oscillograph so that it could be used for photographing lightning surges. This is accomplished by means of the addition of an instantaneous relay actuated by the surge itself. Dr. Norinder made the first successful picture

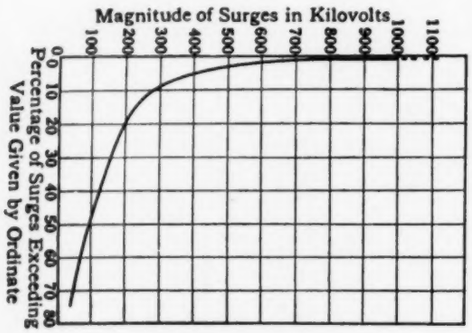


FIG. 1—Curve showing relative voltages of lightning strokes.

of a lightning surge in 1925[3]. Since that time a large number of photographs of lightning surges on various lines have been taken. These records reveal that lightning strokes are of varying intensity and, what is more important, that there is a distinct variation in the steepness of the wave or surge[4]. It is now thought that the cloud does not act as a metallic condenser, but rather, as an accumulation of several small condensers of varying potentials. A break-down is not instantaneous but is a gradually growing streamer emanating from the cloud, fed by successive break-downs within the cloud. The building up of this streamer entails considerable energy loss and the potential of the cloud is greatly reduced before the head of the lightning bolt reaches a grounded object. The entire charge of the cloud cannot be discharged at once, even after the path has been established, but readjustment within the cloud causes one or more recurrences in the same path after the original bolt has collapsed. If lightning is of this nature, it is impossible for any induced voltage from such a stroke to reach potentials dangerous to a well insulated line[5]. That this is so, has also been proven by the oscillograph. This logically leads to the conclusion that what causes trouble on high voltage transmission lines is not induced surges but direct strokes.

TRANSMISSION LINE PROTECTION

The Use of Controlled Flashover

Protective devices for transmission lines are of two distinct types; those which accept a flashover but endeavor to control this flashover in such a way as to maintain service and those which are designed to prevent flashovers. Probably the oldest type of protection was the old horn gap arrester used on DC trolley feeders where the magnetic field produced by the current in the arc was utilized to push the arc up between a pair of gradually spreading horns until the voltage was insufficient to maintain it. Later improvements resulted in the multiple gap arrester and the water jet arrester. The trouble with these devices was that their effect was local and they would have to be placed at every support on the line in order to furnish the necessary protection. To overcome this difficulty, the arc suppressor was developed. This device utilized electro magnetic and electro static relays for shorting or grounding the line either through fuses or through an oil circuit breaker. If a fuse was used it had to be dimensioned so as to lower the voltage sufficiently to quench the arc at the point of flashover and yet blow quickly enough to maintain synchronism. If a grounding oil circuit breaker was used it was set to reopen at a predetermined time.

Such an arc suppressor was installed on the Pennsylvania Water & Power Company's 69 Kv. system in 1912 and was backed up by another form of suppressor called a "field destroying device." This consisted of a relay which opened the generator fields and reclosed them after a predetermined interval. Generally speaking, the devices were successful but required careful adjustment and introduced certain

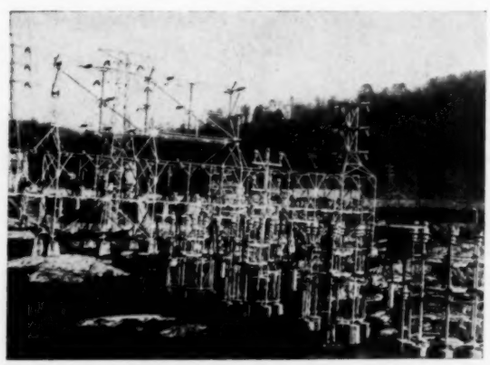


FIG. 2—An arc-extinguisher installation at Holtwood, Pa.

complications. In order to get satisfactory operation, the fuses had to be graded according to the generator capacity connected to the line. During its several years of operation, the arc suppressor prevented many interruptions but occasionally the field destroying device introduced secondary troubles, such as severe hunting of the generators. Under certain conditions the suppressor would operate on low tension troubles which, of course, only complicated matters. It could not be used on anything but a radial feeder as any back feed maintained sufficient voltage at the point of fault to prevent the quenching of the arc.

The so-called "Peterson Coil," designed to suppress arcing grounds, is another form of arc suppressor. This consists of a reactance coil placed between the transformer neutral and the ground. The coil is designed to introduce a reactive component to ground of the correct magnitude to counterbalance the charging current, reducing the current at the fault sufficiently to suppress the arc. Of course, the coil can never be mathematically correct, except for a single fault location and it also introduces some undesirable results or effects during switching operations. The device is commonlyy used in Europe, even on high voltages, but only one or two installa-

tions have been made in this country. Records of their operation, apparently, are satisfactory.

The fused grading ring is another form of arc suppressor, utilizing controlled flashover for line protection. In this device any flashover across an insulator string is forced through an expulsion fuse and the blowing of the fuse will deionize the arc path sufficiently to extinguish the arc. The use of fuses at every insulator string on a transmission line requires a large amount of labor for inspection and replacement of fuses after every storm. To avoid this, the Deion tube, or expulsion arrester, was developed. This is a fibre tube with a metal cap at either end. The metal caps serve as points of contact and are extended down inside the tube so that any breakdown will take place inside rather than on the outside of the tube. The resulting blast quenches the arc . Manufacturers claim a tube is good for at least fifty discharges and, therefore, inspection for tube replacements may be reduced to not more than one a year.

Where momentary interruptions can be tolerated, it is important to protect insulators and cables from the power arcs. This can be done by means of arcing

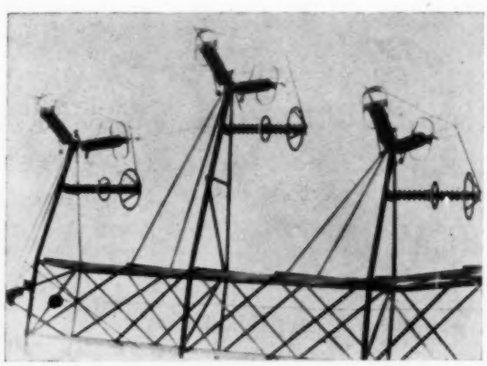


FIG. 3—Fused grading rings and line type arresters on tower—side view.

horns or so-called grading rings. These devices are spill gaps in parallel with the insulators, adjusted so that a flashover will take place across the gap rather than across the insulator string. They are not entirely effective as arcs have been known to leave the gaps and involve the insulator and, in some cases, also the conductor. Where modern high speed switching is used, this in itself, is a protection against damage from power arcs and makes other protective devices used for this purpose less important—if not unnecessary.

Lightning Arresters

Valve type arresters are among devices designed to prevent line flashovers. These were tried out on the system as early as 1911, when three sets of electrolytic arresters were placed on the circuits supplying Holtwood power to Baltimore. One year's trial showed that the maintenance and upkeep of these arresters by far outweighed any possible benefits that could be derived from them and they were consequently disconnected. The reason for the failure of these arresters to protect the line was the fact that they could protect only against surges within a few hundred feet of their location.

A few years ago an experiment with a new type of arrester specifically designed for line protection was made. A 22 mile 69 Kv. circuit was equipped with a set of line type arresters at every fourth tower. While some benefit was derived from this installation, such benefit was not sufficient to make the scheme economically attractive. Probably the discharge capacity of this type of arrester is not sufficiently high to take care of all direct strokes.

Increase In Insulation Level

The value of detailed records of line performance was forcibly demonstrated to the Pennsylvania Water & Power Company after its first year of operation. The records showed that the flashovers during the 1911 season were concentrated on two short sections of the line. Two units were added to each insulator string in these sections. This resulted in a considerable improvement during the following season and, consequently, the additional insulation was extended over the entire circuit. All of the expected improvement failed to materialize but there was less loss of synchronous load. This was due to three wire shorts being practically eliminated. A close scrutiny of the records showed that most of the flashovers had taken place from conductor to the crossarm below, rather than across the insulator. In other words, the crossarm spacing was insufficient for the longer insulator string. The second circuit was then reinforced with one unit per string and its subsequent performance much improved.

The lines of this company today are heavily insulated, using from 7 to 10 units at 69 Kv. and 18 to 20 units at 230 Kv. As a result of the experience just mentioned, tower clearances have been correspondingly increased.

Ground Wires

Ground wires properly applied are today the most effective means for protecting a transmission line against lightning discharges. They have been used as long as have transmission lines but they have had a rather hectic history. Early installations were ofttimes made in a haphazard manner and troubles from breaking of the ground wire and other contacts with the conductors were frequent. On pole lines, particularly, clearances were often insufficient. Ground connections were infrequent and poorly made. Under such conditions, the amount of protection furnished by the ground wire was more than out-weighed by the reduction in insulation due to its use. False conclusions were frequently drawn because of insufficient understanding of the factors involved. In a report made by the Overhead Systems Committee of the N.E.L.A. in 1921 Pennsylvania Water & Power Company is quoted as stating "of two parallel transmission lines, one protected with one ground wire and one protected with two ground wires, the one with the two ground wires had more interruptions than the one with a single ground wire, and, therefore, the benefit of the ground wire is, to say the least, doubtful." We know now that the reason for this lies,

not with the ground wire, but with the lighter insulation used on the line with the two ground wires. We also now know that the primary function of the ground wire is to intercept the lightning stroke before it can hit the conductors and that separations must be sufficient to prevent flashovers from ground wire to conductor.

Let it be assumed that a lightning bolt strikes a ground wire in mid span. There will then be a surge travelling in each direction from the point of stroke towards the supports and continuing through the ground connections down towards ground[7]. If the ground resistance is low, a reflection of opposite polarity will take place, tending to lower the potential at the top of the structure and also on the ground wire. As a result of the coupling between the ground wire and the conductor, a certain percentage of the potential on the ground wire will appear on the conductor and the stress across the insulator will be the difference between this potential and the potential of the structure. For a balanced design, the clearance between the ground wire and the conductor should be such that the likelihood of a side flash from the ground wire to the conductor at the instant of stroke will be the same as the likelihood of a flashover across the insulator.

As the magnitude of the potential at the top of the structure is reduced in proportion to the ground resistance, it is of importance that this resistance be made as low as possible. Where the soil is such that the ground resistance is naturally high, it is economically hopeless to lower it effectively. Fortunately, there are other remedies. Mr. Fortescue of the Westinghouse Company, in a paper delivered at the Mid-winter Convention of the American Institute of Electrical Engineers outlined a theory of a counterpoise for transmission lines. The counterpoise is a metallic wire laid in the ground from structure to structure. The purpose of this wire is to increase the coupling between the ground wire and the conductor and thereby decrease the stress across the insulator. It is known from Faraday's experiment that if a metallic cage is charged with electricity no potential gradient exists inside the cage. The overhead ground wire is part of such a cage and the counterpoise wire, correspondingly, is part of the opposite side of the cage. The more effective the counterpoise, the closer the potential induced on the conductors will approach that existing on the ground wire, and the lower will become the gradient across the insulation.

In the last few years much experimental work has been carried on, using wood in the structures to back up the porcelain insulation on transmission lines[8]. Wood braces on pole lines, long wood insulators in guys, wood crossarms on steel towers, are being given trial. Judging by laboratory experiments, considerable benefits can be expected from such construction but available records from actual installations do not always confirm this, except in the lower voltage classes. It appears that the wood insulation, where clearances are large as compared with the operating voltage, does not prevent the original impulse flashover as much as it prevents the power follow-up.

Summary

The scheme of protection for transmission lines divides itself in two groups according to voltage. For lines below 66,000 volts it appears uneconomical to apply enough insulation to make the ground wire effective and for these lower voltages other methods of protection, such as fuses or Deion tubes, or wood insulation, seem to recommend themselves. When ground wires are used on wood pole construction the down leads should be carried well away from the poles or structure so as not to lose any benefit from the insulating quality of the wood.

In the higher voltage classes it appears feasible to furnish sufficient line protection by means of insulation, ground wires, and counterpoises, and thus make other devices unnecessary.

The recent 230 Kv. line built by the Pennsylvania Water & Power Company has been designed in accordance with the latest ideas of ground wire protection. Two ground wires are located 30 feet above the conductors and ample insulation and clearances provided.

A surge generator was used to check the location of the ground wires for protective performance and electrical clearances. Ground wire location was checked on small scale models while clearances were checked on the full size structure. In no case in the model tests did the impulse stroke directly hit the power conductors. Strokes contacted either with the ground wires or the ground itself.

The tower footing resistances on this line have been lowered as far as economical by the use of ground rods and four 50 foot wires, each run diagonally from a corner of the tower, terminating in a ground rod. Counterpoise was installed along a five mile section of the line.

Two lightning seasons have passed with only one interruption caused by a single wire flashover during a lightning storm on the 12th of June, 1933. This, and the excellent record of other high voltage lines, indicates that the dependability of transmission today is very definitely improved. Further research work now going on justifies the hope that a truly lightning proof transmission service may be developed within economic limits in the not too distant future.

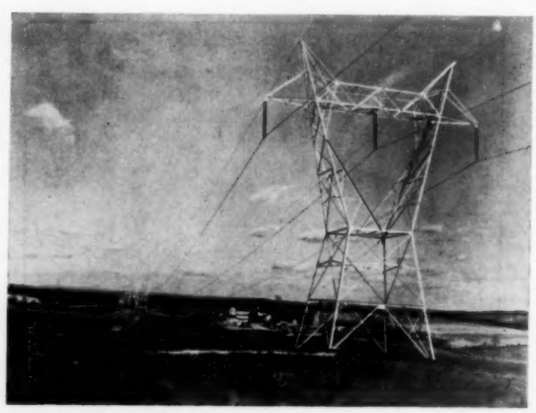


FIG. 4—Typical tower for Safe Harbor-Westport 230 Kv. Line.

ELECTRIC STATION PROTECTION

General

The fundamental problem encountered in the protection of electric stations against lightning is the same as that for transmission lines, that is, the prevention of failure of insulation. The protective methods used, however, differ. The transmission line depends for its insulation largely on porcelain or wood, whereas the insulation of stations and connected apparatus is more complex. Because of the simplicity of insulation structure it may be economical to raise the insulation level of transmission lines to a high value. This is not generally the fact in the case of electric stations because of the cost of apparatus at such high insulation. Here the voltage permitted must be kept at a lower level and greater duty is thrown on station protective equipment.

Early Design

The early designs of station insulation and protective equipment were largely based on experience

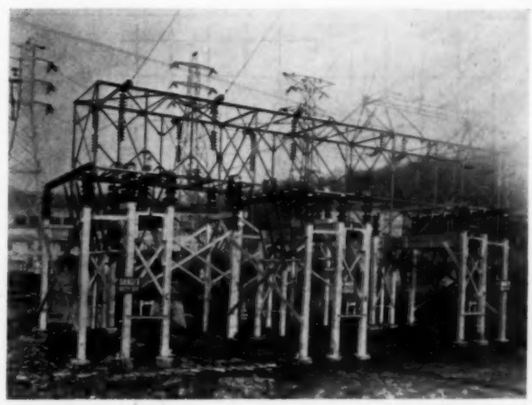


FIG. 5—Repeating Fuse Gap Arrester—Holtwood Station.

factors and were made without the benefit of the fundamental data which has become available to the industry in the last few years. Many of the earlier stations suffered from insufficient insulation in both apparatus and conductor supports. Protection against lightning usually consisted of the application of lightning arresters either on the incoming lines or on the station buses. The protective performance of these arresters was often unsatisfactory. Failures due to misapplication were not uncommon. As a result, there appeared a growing tendency to consider the lightning arrester with suspicion, and often to omit it entirely.

As transmission engineers increased the insulation levels of the lines in an attempt to reduce outages from lightning, flashovers and surges increased in the stations, particularly where ground wires or arresters were omitted. It was comparatively easy to run up bus insulation, bushing insulation and switch insulation and this was often done with the result that the punishment was transferred to more expensive apparatus.

Little data on insulation strength, other than that at 60 cycles, was available to the designer. Even the 60 cycle levels used by manufacturers differed. Station designs could neither be coordinated nor standardized. If station insulation levels were raised to correspond to those of the line an uneconomical design resulted; if station levels were kept at normal values frequent outages were experienced. Conditions were almost chaotic[9-10].

The system of the Pennsylvania Water & Power Company did not escape the difficulties encountered by others. New 69 Kv. lines and stations installed in 1923 were over-insulated and ground wires and lightning arresters were omitted. Repeated lightning flashovers were experienced on the transformer bushings. The design of these was none too good and in addition to flashing over they repeatedly blew to pieces. After two years' operation they were replaced by higher voltage bushings of an improved design. This reduced the flashovers to some extent and completely eliminated damage to the bushings but, of course, transferred the strain directly to the internal parts of the transformers. There then followed in quick succession several tap changer failures. Fortunately, after new tap changers of increased strength were installed no further failures were encountered in these units.

Fused grading rings, reduction of insulation adjacent to the stations and other similar means were tried in attempts to reduce transformer bushing flashovers but without success. Finally ground wires were installed on all lines for a distance of at least two miles from the stations and lightning arresters added on all circuits. There have been only one or two bushing flashovers in the 69 Kv. stations of this system in the five years since the completion of this change, although the equipment is now operating with bushing insulation only slightly in excess of 69 Kv. standards.

An interesting lightning arrester which was developed during this trial period of design was a special repeating fuse gap arrester.

The gap consisted of bowl shaped cast discs having parallel flat center sections which, approaching the shape of infinite spheres, were intended to operate with minimum time lag. In series with each gap was a set of six fuses so connected that as each fuse blew the next fuse was inserted in the circuit. As many as three fuses per phase have blown on one of these arresters during a storm without outage of a line or flashover of equipment.

These arresters have given very satisfactory service during their period of operation but their cost, large space requirement, the necessity for reloading and the improvements in modern standard arresters have removed the incentive for the construction of additional units.

Progress In Impulse Studies

The steady progress during the last five years has made available much needed data on impulse strength of insulation. The data thus collected, although far from complete, provides a basis on which to formulate design of modern station insulation and lightning protection. Insulation levels and lightning protection are closely related and will be treated together.

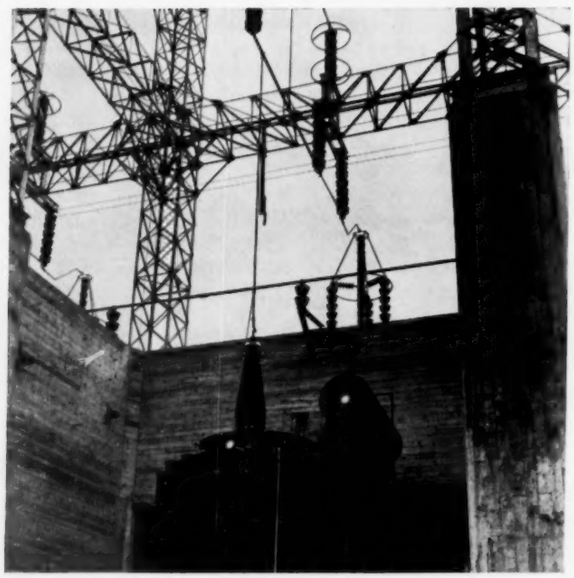


FIG. 6—Transformer, Coordinating Gap and Lightning Arrester.

The breakdown of a given insulation involves two factors, time and voltage. For a wave of definite shape the time required to cause breakdown decreases as the crest voltage increases. This characteristic is called the time lag of insulation. Curves showing time lag against voltage for various insulations have been secured in the laboratory. Such curves are used as a basis for comparing insulation values and determining protective requirements.

Coordination of Insulation

Coordination of insulation may be defined as the application of insulation and protective equipment, coordinated to provide adequate factors of safety at the voltages expected.

In station design the coordination is generally such that the more important and less easily replaced equipment has the greatest factor of safety. It is obviously uneconomical to attempt to insulate against the maximum values of lightning surges which may occur. It is necessary then, by the use of protective methods, to reduce these surge voltages to values which may be withstood with economical levels of insulation.

Accumulated experience, in combination with the more lately acquired data on impulse characteristics of insulation, have now made it possible to establish definite insulation levels for voltage classes for 15 Kv. to 230 Kv. These are expressed tentatively in terms of inches of standard gap, the flashover characteristics of which are reproducible within fairly close limits in the various laboratories.

Tentative insulation gaps have also been established for levels below 15 Kv.; however, only a relatively small amount of work has been accomplished at these voltages and difficulty will still be experienced for some time to come in rationalizing insulation at these levels.

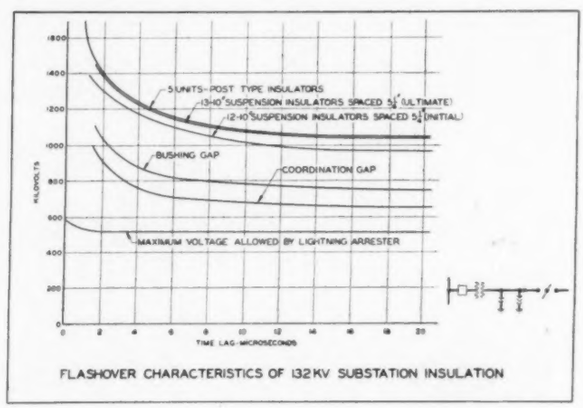
Coordinating Gaps

A protective gap, used to establish the insulation level in a station, is called a coordinating gap. By the use of a coordinating gap and lightning protective devices station insulation may be kept at a level which is independent of the insulation level of the transmission lines. This will permit the transmission line designer to raise his line insulation to meet line problems without forcing either an uneconomical insulation level increase on the stations or throwing an excessive strain on the station insulation and apparatus.

This coordinating gap should be designed to withstand normal switching surges without flashover.

The logical location for the coordinating gap is at the entrance to a station, however, if the station is large and this gap is more than 50 circuit feet from important equipment at voltages below 69 Kv. and more than 100 feet at voltages of 69 Kv. and above, additional gaps may be necessary at the equipment.

Recent investigation by the manufacturers has indicated that coordinating gaps if used alone may not protect or may only offer reduced protection to equipment insulation if the incoming wave has a high



FLASHOVER CHARACTERISTICS OF 132 KV SUBSTATION INSULATION

FIG. 7—Insulation Coordination—132 Kv. Outdoor Substation.

crest and very steep front[17-18]. Under these conditions the high voltage existing during the time required for the gap to break down may damage the major insulation of the equipment. Waves of this severity are rare and are probably produced only by direct strokes on the conductors in or near the station.

Figure 7 illustrates the application of the coordination principle to a 132 Kv. substation now in process of design. It will be noted that the protective lightning arrester and the spill gap will be located inside of the line switch; this switch has therefore been insulated more heavily than is usual, so that its insulation strength when open will correspond to that of the line. The transformer insulation level is not definitely known; it is however, well in excess of the bushing gap.

Ground Wire Protection Over Incoming Circuits

To reduce the possibility of direct stroke on conductors near stations, ground wire protection should

be installed on all incoming lines for several thousand feet adjacent to the station.

It is important that ground wire protection for the line be extended into the station area and not terminated at the first tower as such a discontinuity changes the surge impedance of the line and will cause a rise in voltage.

Ground Wire Protection Over Station Areas

A properly designed ground wire system for the station itself, is of prime importance.

The design of the shielding system should be such as to allow each conductor to fall within the protective zone. For ground wires, analysis indicates that the protective zone is represented roughly by the area of an isosceles triangle, the height of which is the height of the ground wire above the ground and the base of which lies on the ground and extends a distance on either side of the ground wire equal to one to two times the wire height.

Where ground wires do not appear to be economical or their installation is not feasible on account of equipment location lightning rods may offer effective protection. It is usually estimated that a

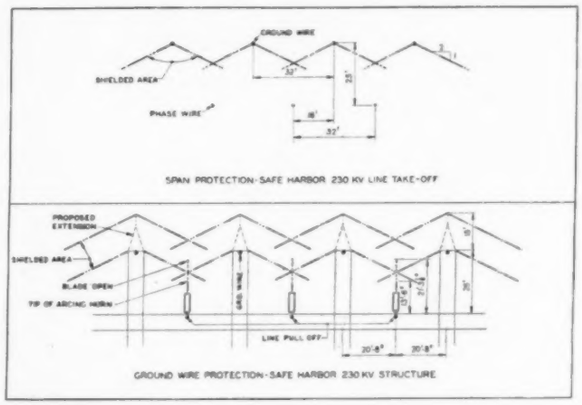


FIG. 8—Ground Wire Protection—Safe Harbor Hydro Electric Station.

shielding zone with a diameter of four times the height is produced by such lightning rods.

Lightning Arresters

The lightning arrester is the first line of defense in the protection of electric stations against lightning. The logical location is adjacent to the coordinating gap.

The lightning arrester is intended to prevent the entrance of dangerous travelling waves into the stations and to hold reflected surges to levels below the flashover of insulation. Since the coordinating point gap is not an ideal protective device (because it secures its protective characteristics by permitting a flashover) an important duty of the lightning arrester is to prevent gap flashover. Conversely the gap acts as a constant check on the efficiency of the arrester. The gap is the secondary line of defense and is intended to function if the lightning arresters are out of service or if for some reason their protective ratio has been reduced.

The protective value of lightning arresters is subject to constant investigation both in the field and in the laboratory. Positive improvement has been achieved in performance. Unfortunately a corresponding improvement in maintenance reduction has not been effected. The chief trouble seems to be due to moisture, which in entering the arrester not only corrodes or destroys important parts but at the same time reduces the protective value.

Operation Without Lightning Arresters

On some properties, particularly in substations of higher voltage successful operation has been obtained without lightning arresters, by the use of higher insulation levels and gap clearances, combined with effective ground wire protection. The use of such protection is purely an economic matter, but it is not believed that it will be successful at the lower voltages.

In line sectionalizing substations where disconnecting or load break switches only are employed it is usually economical to omit lightning arrester protection. In these installations switch and bus insulation should be raised to a level equal to that of the transmission line. Adequate ground wire protection is vital if the same service continuity is to be secured from the substation as from the line. This ground wire protection must be effective with the switches in the open position as open switch blades have been found a potential source of trouble from direct strokes.

In small substations, where arrester protection cannot be justified, fused grading rings are sometimes used. These are generally of the single or double fuse type on account of simplicity and low cost.

Station Grounds

An effective ground is an important link in the

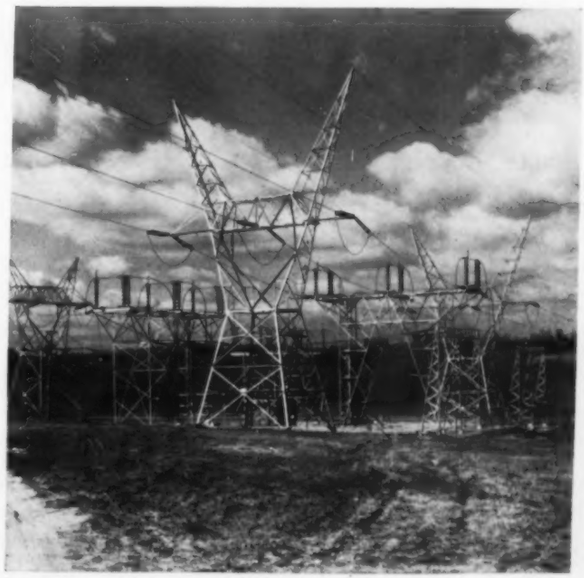


FIG. 9—Ellicott Substation—Safe Harbor, Baltimore, Washington—230 Kv. Interconnection.

station protective system. Such a ground should be of low resistance and surge impedance and may be secured by driven grounds or cable networks, or a combination of the two.

Lightning arrester and spill gap ground connections should be as short and direct as possible. A direct connection from the shielding system to ground is always desirable, as this will reduce the voltage differential across the station insulation.

It is now general practice to connect transformer neutral, lightning arrester, equipment and all other grounds together solidly.

Protection of Machines Directly Connected to Overhead Lines

The protection of rotating A.C. machinery against lightning surges is more difficult than that of transformers and similar apparatus. This is due to the fact that the impulse ratio* of the type of insulation used in armature windings is only slightly greater than unity, whereas that of transformers and associated equipment is in the order of 2:2. It has been recommended, therefore, that for safe practice in selecting protective equipment the maximum allowable surge voltage to which the machine can be subjected be limited to the crest value of its high potential A.C. test[13-14-19].

The stresses which lightning over-voltages produce in a rotating A.C. machine may be divided in two classes:

1. Stresses produced by the voltage from coil to ground, which is mainly a question of the crest value of the surge.
2. Stresses due to the voltage from turn to turn, which is primarily a question of the steepness of the wave front.

The scheme of protection must, therefore, not only limit the voltage to ground but also slope off the incoming wave sufficiently to keep the turn voltage gradient within safe limits.

One recommended method of protection for grounded neutral machines involves the use of a standard line type arrester on the incoming line about 1500 feet from the machine. A second arrester in parallel with a capacitor is placed at the machine terminals. The purpose of the first arrester is to limit the crest value of the incoming surges. The function of the capacitor is to limit the rate of voltage rise (wave front) of the surge passed onto the machine. The second arrester, which is a special design, operates to limit the maximum voltage appearing across the capacitor and thus allows a much smaller unit to be used.

When the neutral is ungrounded or the machine delta connected the protection is more difficult since the traveling wave impressed on the winding may approximately double in value at the neutral of the winding. The entering surge in each machine must, therefore, be held to a value about half of the normal crest voltage if the impulse ratio limit previously mentioned is to be adhered to. In the case of ungrounded machines the method of using a capacitor in parallel with a special arrester cannot be used, since no arrester at present developed can operate within the narrow limits necessary. The use of a large capacitor which will assist in voltage reduction while sloping the wave front, in conjunction with the line arrester and ground wire protection seems to be the most practical solution to the problem available at present.

* Ratio of impulse crest to 60 cycle crest breakdown.

Protection of Machines Connected to Lines Through Transformers

It has been shown that impulse voltages may pass through transformer banks by either electromagnetic or electrostatic induction[15].

The severity of the surge voltage which appears at low tension equipment depends on the magnitude and wave shape of the applied voltage and on the size, constants, ratio and connections of the transformer banks. Lightning arresters on the high voltage side of transformers, if properly applied, will provide sufficient protection for coil insulation of machines operating on the low tension bus. A capacitor or a capacitor and lightning arrester may be used to protect turn insulation, if necessary.

The majority of machines connected to transmission lines through transformers are operating with no lightning protection on the secondary side. Some failures of insulation on such machines have occurred, but compared to the total number of machines in service they appear negligible. From this it would seem that the transformers and their high voltage lightning arresters, form an effective barrier against surges originating on overhead lines.

The machines in the generating stations of the Pennsylvania Water & Power Company operate ungrounded and are connected to transmission lines through transformers. In twenty-five years of operation four failures attributable to the passage of lightning through transformer banks, have been experienced. These all occurred within a two year period, and at that time when lightning arresters were not used on the high voltage side of the power transformers. There have been no difficulties experienced with these machines since high voltage lightning arresters and ground wires have been applied on this system.

Conclusions

Within the past five years marked advance has been made in the study of lightning theory, impulse technique and testing, insulation coordination, and impulse strength of insulation and apparatus.

By effective ground wire installation on lines and in stations it is practicable to design a high voltage power system so that the probability of direct hits on conductors or apparatus is low. This largely removes the most dangerous source of the higher voltage surges.

It would seem advisable that stations be designed so that they are:

1. Shielded from direct strokes:
   If indoors this is automatically taken care of by the building; if outdoors shielding may be accomplished by ground wires of sufficient height and spacing to intercept lightning discharges to buses and terminals.

2. Protected against incoming surges of magnitude dangerous to insulation and apparatus by:
   a. Use of ground wire protection over incoming lines for a distance of at least ½ mile from the station.
   b. The limitation of incoming traveling waves by the use of coordinating gaps and lightning arresters.
   c. The adoption of an adequate insulation level for buses, taps and apparatus. This level should be stronger than and coordinated with the gap and arrester protective devices, and above normal switching surges.
   d. The installation of an adequate station grounding system.

BIBLIOGRAPHY

1. Lightning and other Transients on Transmission Lines, F. W. Peek, Jr., A. I. E. E. Vol. 43, October, 1924, p. 1205.
2. The Klydonograph, J. F. Peters, Electrical World, Vol. 83, April 19, 1924, pp. 769-773.
3. The Cathode Oscillograph as used in the Study of Lightning and other Surges on Transmission Lines, Harold Norinder, Trans. A. I. E. E. Vol. 47, No. 2, p. 446.
4. Lightning Laboratory at Stillwater, New Jersey, R. W. Conwell and C. L. Fortescue, A. I. E. E. Vol. 49, July, 1930, pp. 872-876.
5. Lightning Stroke, Some Theoretical Speculations, L. V. Bewley, General Electric Review, December, 1933, p. 516.
6. The Neutral Grounding Reactor, W. W. Lewis, A. I. E. E. Vol. 42, 1923, pp. 417-434.
7. Transmission Tower Design for Maximum Lightning Protection, C. L. Fortescue, Electric Journal Vol. 27, November, 1930, pp. 640-644.
8. Impulse Tests on Wood Line Material, J. J. Torok and W. R. Ellis, Electric Journal, August, 1933, p. 347.
9. Relation between Transmission Line Insulation and Transformer Insulation, W. W. Lewis, Trans. A. I. E. E. Vol. 47, No. 4, p. 992.
10. Rationalization of Transmission System Insulation Strength, Philip Sporn, Trans. A. I. E. E. Vol. 47, No. 4, p. 998.
11. Rationalization of Station Insulating Structures with Respect to Insulation of the Transmission Line, C. L. Fortescue, Trans. A. I. E. E. Vol. 49, No. 4, p. 1450.
12. Recommendations on Balancing Transformer and Line Insulation on Basis of Impulse Voltage Strength, V. M. Montsinger and W. M. Dann, Trans. A. I. E. E. Vol. 49, No. 4, p. 1478.
13. Effects of Lightning Voltage on Rotating Machines and Methods of Protecting Against Them, F. D. Fielder and Edward Beck, Trans. A. I. E. E. Vol. 49, No. 4, p. 1577.
14. Voltage Oscillations in Armature Windings under Lightning Impulses I, E. W. Boehne, Trans. A. I. E. E. Vol. 49, No. 4, p. 1587.
15. Effect of Transient Voltages on Power Transformer Design IV, K. K. Palueff and J. H. Hagenguth, Trans. A. I. E. E. Vol. 51, No. 3, p. 601.
16. The Coordination of Transformer Insulation with Line Insulation, V. M. Montsinger and W. M. Dann, Trans. A. I. E. E. Vol. 51, No. 4, p. 923.
17. Factors Influencing the Insulation Coordination of Transformers, F. J. Vogel, Trans. A. I. E. E. Vol. 52, No. 2, p. 411.
18. Coordination of Insulation, V. M. Montsinger, W. L. Loyd, Jr., and J. E. Clem, Trans. A. I. E. E. Vol. 52, No. 2, p. 417.
19. Protection of Rotating A.C. Machines Against Travelling Wave Voltages due to Lightning, W. J. Rudge, Jr., R. W. Weisman and W. W. Lewis, Trans. A. I. E. E. Vol. 52, No. 2, p. 434.

DISCUSSION

Discussion presented by

W. H. Burr, Electrical and Mechanical Superintendent, Lukens Steel Company, Coatesville, Pa.
F. A. Allner, Vice President, Pennsylvania Water & Power Company, Baltimore, Md.
J. C. Reed, Electrical Engineer, Bethlehem Steel Company, Steelton, Pa.
L. H. Fister, Power Foreman, Bethlehem Steel Company, Sparrows Point, Md.
B. Van Ness, Jr., Electrical Engineer, Pennsylvania Water & Power Company, Baltimore, Md.
A. J. Standing, Electrical Superintendent, Bethlehem Steel Company, Bethlehem, Pa.
E. Hansson, Transmission Engineer, Pennsylvania Water & Power Company, Baltimore, Md.
H. H. Angel, Electrical Dept., Bethlehem Steel Company, Sparrows Point, Md.
E. L. Anderson, Electrical Dept., Bethlehem Steel Company, Sparrows Point, Md.
H. D. Esterly, Electrical Engineer, Alan Wood Steel Company, Conshohocken, Pa.

W. H. Burr: To open the discussion, I will call upon Mr. F. A. Allner, Vice President of the Pennsylvania Water and Power Company, and I am wondering if he has anything to say to us at this particular time.

F. A. Allner: It is a great pleasure to be here with you tonight and I especially welcomed this opportunity of seeing again Mr. Burr, who had been one of our old cronies back in the early days at Holtwood. I think he was instrumental, if I remember correctly, in installing some of the apparatus for one of the leading manufacturers, which was designed and put into operation at a time when as little, perhaps, was known to us of lightning, of the mechanics of lightning, of the best ways of coping with it, as to the proverbial babes in the woods.

I am glad to see the response which the industrial and other users of electric power have given to the efforts of the power companies in co-operating toward the solution of this problem, especially engineers in such a big powerful industry like the steel business, who have their time and thought taken up with the task of producing tonnage or quality and, in many cases, both together. These engineers, I believe, have shown ever since the formation of your

Association a valuable understanding of the problem that arises outside of their own sphere of activity, and it is this co-operation which I believe has made it largely possible for the power producing and transmitting company to tackle this job in the course of time and with a little more success than it could see about twenty years ago.

J. C. Reed: I don't know that there is anything I can say regarding lightning. Of course, I could reminice some, but I'll not do that tonight. In the steel business we usually do not come into contact with such high voltage circuits on transmission lines as those we have heard discussed here this evening. Our transmission lines are of comparatively low voltage and comparatively short distances. My own preference, however, in the way of protection, has been that of ground wires, where they can be used, and that is probably due to something that Dr. Steinmetz told to me some twenty-five or more years ago. I happened to meet up with him on a Pullman train one time and we were in the smoking car. After we had smoked everybody else out of the compartment, we started to talk about lightning protection, and his formula for it, as he told me at the time, was that the best thing you could do, if you couldn't put your wires under the ground, was to get plenty of ground above your wires. That was just the way he told it to me, and I suppose he thought that that was about as far, in a theoretical way, as I was capable of comprehending the thing, which wasn't very far from the truth at that. When it comes to discussing this paper, I am somewhat in the position of a woman who happened to be crossing a bridge from which a little boy was fishing, and just as she passed, the boy pulled out a fish about four inches long. She said, "Oh, this is terrible, that poor little fish—it's cruelty to dumb animals to do that. You ought to be ashamed of yourself." The boy replied, "Aw, lady, if that fish had kept his mouth shut, he wouldn't have gotten into trouble."

L. H. Fister: There was one question I would like to ask Mr. Van Ness: What would be the advantage, if any, of grounding a D.C. control circuit, running parallel to transmission system, about 25 feet underneath the transmission system, ,and grounding one side of it?

B. Van Ness, Jr.: Is it in a lead sheath?

L. H. Fister: No, it is open wiring, 230 volts D.C.

B. Van Ness, Jr.: It is dangerous to ground control systems. I believe that the use of adequate insulation would do much more good than grounding one side of the cable.

L. H. Fister: That's just the question we have in mind at Bethlehem. We have the condition where we have the 230 volt D.C. system grounded, and the result has been, I think, that we have got a lot of trouble on our protective relays.

B. Van Ness, Jr.: Yes, grounds on control systems are very dangerous because if you get a ground on the other wire you will have a short. But the use of a grounded lead sheath may help if you can install a cable; perhaps stronger insulators and lightning arresters at the station may be the answer.

The telephone company has found in cable work that the most satisfactory results are obtained if the cable sheaths are grounded. Lightning arresters are connected between conductors and sheath.

A. J. Standing: This has been a very interesting discussion. I am particularly interested in grounds. To state our case in the steel plant, we run 6600 volt, three phase, 25 cycle ungrounded system. That's a premise. We run overhead ground wires, and we are trying our structures to ground as carefully as we possibly can. I am interested in ground resistance values and I'm wondering if any studies are being made of them and of what value they would mean to us under the conditions I am speaking of. In several cases where we have had trouble, we have run very heavy grounds between substations and other buildings, creating in effect a parallel system of grounds. We use a million circular mill wire laid to ground and welded to buildings and structures to tie the whole structure together, forming a more perfect ground in a parallel path. We had a very interesting job last summer. We had to run a new steel tower line, about a mile and a half to a coke plant, and about three-quarters of a mile of this traversed a cinder dump. If you know what a cinder dump is, it's a gigantic insulator difficult to get a good ground on it anywhere, and we have had a good deal of trouble from this source. The new line runs on steel towers ranging about eighty-five feet in height, with two lines of 300,000 circular mill wire each, and a single ground wire on top of the towers was also a 300,000 bare copper ground wire. And, in the midst of the cinder dump is a small creek, fortunately, and we took this ground wire to the bed of the creek and put in quite a network of copper bus wiring and tied the towers together as best we could. So far, we haven't had any trouble on that line. We use two types of the most accepted lightning arresters in and around our substations, but I think we are going to continue the tying together of the various structures and increasing our ground wherever possible.

E. Hansson: Did I understand that it is a 6600 volt line?

A. J. Standing: Yes, ungrounded.

E. Hansson: With the amount of insulation you would, in all probability have on that line, I would say ground doesn't mean anything at all to you. The principal purpose of a ground wire for a line of this voltage is to guard against induced voltages; whether your ground wire is connected to a good ground, or practically insulated, wouldn't make any difference in this respect.

A. J. Standing: Do you test the value of your ground?

E. Hansson: Yes, we test them. We are trying to get them down as low as economical. On the Safe Harbor line, for instance, after having completed the first grounding, which consists in placing the counterpoise wiring around the towers, we measured up the combinations. Then we struck certain levels and determined about what we could afford to do in addition to this. We did bring them to an average of about thirty-six ohms, and have nothing above forty ohms at the present time.

A. J. Standing: To what expense would you go to arrive at better ground conditions—diverting your line or anything like that?

E. Hansson: Whatever we can stand in expense, of course. In case you can't get satisfactory grounds and you install continuous counterpoises, you're just as well off as if you had low ground resistance at each structure, and that is probably the cheapest way in arriving at your best condition.

A. J. Standing: Counterpoises replacing good normal grounds?

E. Hansson: When you have good grounds you would get little or no benefit from a counterpoise, but where your grounds are bad, is where you get the real benefit. What is a good ground, of course, depends on your insulation on the line; the lower your insulation the better the ground you need; the higher your insulation, the poorer ground you can stand.

B. Van Ness, Jr.: I might add that in stations where it is very difficult to secure a good ground by driven pipes or wells the actual interconnection of grounding wires between equipment, tower footings, building steel, etc., often forms a wonderful counterpoise. I know of one large 230 Kv. substation where both wells and rods were driven. Tested individually, the ground resistances were high, and the ground system as a unit was only relatively low. The station has a very excellent lightning record, which is believed to be largely due to the counterpoise action of the many ground interconnections. I believe your installation, Mr. Standing, is somewhat similar, in that you have multiple ground paths.

H. H. Angel: Well, I have enjoyed listening to these papers very very much, as lightning protection has always been something which we have given serious consideration. We are tied in parallel with the Gas Company system in Baltimore and we have our own generating system, of course, of 6600 volts, and have a very large network around the plants, which means that we must keep our ground wire protection in first-class condition and we are constantly replacing obsolete lightning arresters with those of the latest types and we feel that we have gotten, and are getting, better results as newer developments are being made.

E. L. Anderson: I do not believe that there is much that I can add to the general discussion except to point out that along with the installation of the more modern type arresters at the Maryland Plant we are gradually eliminating the use of choke coils on all 6600 volt circuits. Choke coils apparently do not increase the efficiency of an arrester installation but they are surely a potential source of trouble on any moderate voltage high capacity system.

I would like to congratulate Messrs. Hansson and Van Ness on the papers to which we have just listened.

H. D. Esterly: My experience with lightning I think is very limited, but there is one thing I would like to ask about the insulation on your line: if you have a 220 KVA line, what would be the ratio which you would insulate for?

E. Hansson: When you get up to large volumes of power with high voltages on transmission lines you can neglect the operating voltage; what you want to insulate against is the lightning voltage that you expect to have to withstand, which again, depends entirely on the kind of service that you want to give. As I mentioned before, if you happen to be located in a country where there is no difficulty in getting low ground resistances, you can get along with very much less insulation than you can in a country where it is almost impossible to get low ground resistance. We have lines operating out West, where lightning is not so bad, with twelve units, but here in the East we started out with fourteen and now are up to eighteen units.

A. J. Standing: There is one question that I have, Mr. Chairman. In some of my reading I have noticed there is a tendency to get away from lightning arresters on 220 Kv. lines, and I noticed in your discussion that you referred to the use of arresters continually. What is the trend of thought on that now?

B. Van Ness, Jr.: The school of thought differs, I think. There are some companies that don't like lightning arresters and won't have them. Other companies favor their use.

A. J. Standing: Well, some of them claim they cause more trouble than they eliminate.

B. Van Ness, Jr.: Yes and they increase the insulation levels and install larger gaps. That is purely a matter of service continuity and economics.

We have had generally good protective experience with lightning arresters and have definitely reduced the number of bushing flashovers per year. While we do not believe that arresters are as good as they might be, we favor their use, and install them on all circuits.

A. J. Standing: And your arrester maintenance has not been prohibitive at all?

B. Van Ness, Jr.: It hasn't been what it might be by any means. There is still a lot to be gained by further reducing arrester maintenance. Of course, a great many of us look back on the old days when we used electrolytic arresters and had to tear them down and rebuild them every one or two years; then we did not know whether they were going to blow up or not. Of course, that day is passed but the trouble which has lately been experienced from moisture has necessitated some maintenance. This does not approach the old maintenance in cost.

A. J. Standing: What was the type of arrester which you showed on the screen?

B. Van Ness, Jr.: That was a Westinghouse Autovalve. Incidently there has been no maintenance on that unit that I know of.

A. J. Standing: What voltage?

B. Van Ness, Jr.: 230 Kv.

A. J. Standing: 230 Kv.! That would be a series of arresters?

B. Van Ness, Jr.: A series of gaps and a series of arrester sections.

Electric Overhead Traveling Cranes

By R. J. HARRY,
General Manager, Alliance Machine Company,
Alliance, Ohio.

Paper presented before the Philadelphia District Section of the A. I. & S. E. E., November 3, 1934, and the Pittsburgh District Section, January 12, 1935.

On account of the universal application of electric overhead cranes in industry, a discussion of this subject is always interesting. This is especially true with those who are engaged in the steel industry, as practically every stage of steel production contemplates the use of cranes. In recent years many new features have been incorporated in crane design, and it is the purpose of this paper to discuss some of these new developments.

Appreciating the importance of cranes in industry, engineers, in recent years, have been specifying machines of more rugged construction, finer workmanship, greater accessibility of parts, and the maximum of safety for operator and repairman, as well as the man whose duties require him to work in the building where the cranes operate.

As motors, controllers, and brakes have been developed to withstand the abuse incidental to both normal and abnormal crane operation, the tendency has been toward higher speeds of the various motions. This has been especially true of the bridge motion and has resulted in the installation of much larger motors than were formerly used.

A majority of the crane girders are of box cross section, and of the construction familiarly known as the "Fish Belly" type. This type of girder is the logical one from an engineering standpoint, and uniform stress is obtained throughout the entire length of the span with the loaded trolley in any position. With the small horsepower and equally small torque motors used for driving the bridge motion on the early cranes, it was not deemed necessary to supply the box type crane girders with diaphragms and in many cases the top cover plate, to which the trolley rail is attached, was inadequately supported.

With the increasing speeds of the bridge motion resulting from the use of larger bridge notors, and the installation of more effective foot brakes, it is little wonder that the torsional stresses produced were beyond the power of the inadequately supported girder to resist. The result of continued application of these stresses was twisted girders, and it was not uncommon to observe girders whose vertical axis was several inches out of plumb at the center of the span.

The installation of diaphragms spaced at proper intervals has done much to improve the above condition, but plainly showed the necessity for providing heavier bracing at the ends of the girders where they are attached to the trucks.

In recent years the installation of adequately wide footwalks, demanded by safety laws, large bridge motors, and in many cases the locating of the magnetic control equipment on the footwalk, has led engineers to specify the use of outrigger girders to relieve the main girder of the torsional stresses produced by the heavy overhanging loads and plugging the bridge motor.

The plugging torque and accelerating torque of the bridge motor amplified by the motor gear ratio, generally constitutes the greatest stress producing medium, but if care is not exercised in the selection of the proper size of footbrake, it is easily conceivable that with too large a brake installation the greatest torsional stresses may be produced in the girder by the too rapid deceleration that ensues when the oversized footbrake is severely applied.

Fortunately for the crane girders, overload protection is afforded by the slipping of the crane wheels when too great an amount of torque is applied by the motor or by the brake, and this safety valve should not be nullified by the use of too much sand in the track.

With the higher free running bridge speeds obtainable with series motors and roller bearings, the proper selection of the size and type of bridge footbrake becomes of prime importance.

The Alliance Machine Company has recently developed a new type of bridge drive which, combined with their internal or external hydraulic brakes, is an engineering accomplishment which greatly reduces the stresses obtained with the conventional drive.

Fig. 1, View "A", shows the new type of bridge drive and a typical hydraulic brake installation. This drive can be furnished with the track wheel gear fully enclosed, but located outside of the track wheel bearing.

View "B" shows the new type of bridge drive and typical hydraulic brake installation. In this case the track wheel gear is located adjacent to the track wheel and between the axle bearings.

View "A" is especially adapted for buildings where the distance from the center of rail to face of column is limited, while the construction shown on View "B" is applicable where more space is available.

With either of the drives shown on view "A" or "B" the gears can operate in a bath of oil and drip proof results guaranteed. It will be noted that this

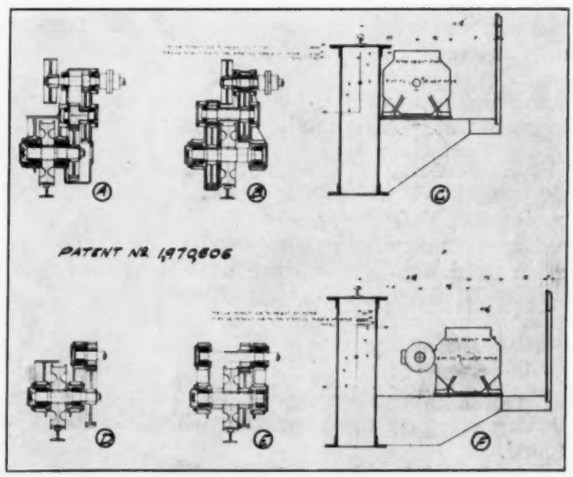


FIG. 1

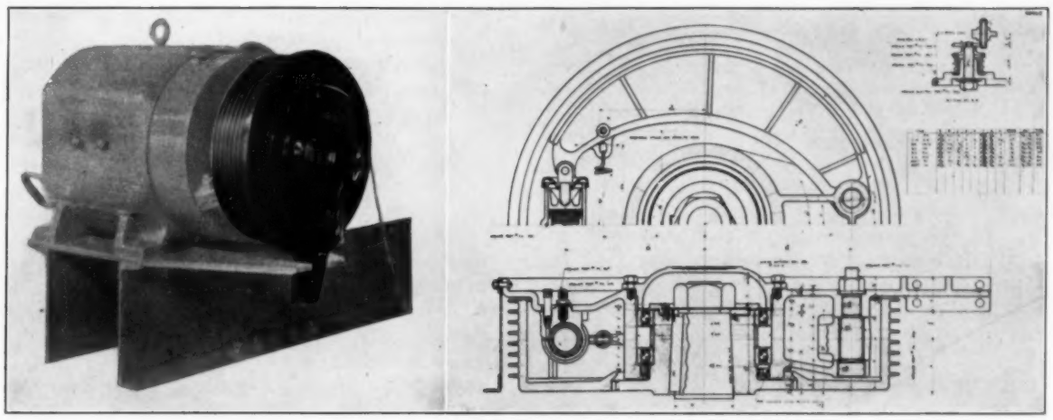


FIG. 2

construction lends itself admirably to the use of hydraulic brakes—two brakes being used, one mounted on each end truck at the end of the line shaft, which with this construction rotates at armature speed with armature torque. The two brakes, one at each end of the line shaft, are both bound to act in synchronism and with equal retarding torque. With this construction none of the decelerating torque due to the inertia of the crane is transmitted to the crane girder through the line shaft when the brake is applied; torque being produced in the girder only when the motor is energized for acceleration or plugging, and

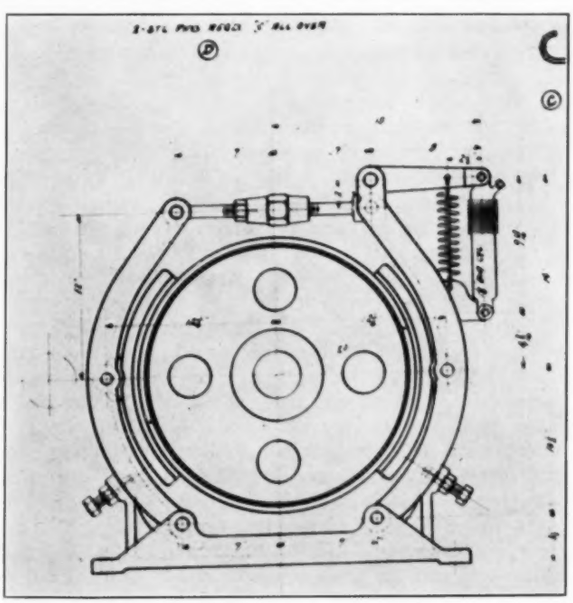


FIG. 3

since no gear reduction is used at center of girder, this torque is correspondingly reduced from that of old construction. With the use of magnetic control the forces produced in accelerating and plugging can be controlled so as to keep the stresses developed within safe limits.

View "C" shows a cross section of the crane girder at the center and indicates the location of the bridge motor with reference to the girder as it obtains with the new drive. Not only is the distance from the center of motor to center of girder reduced to a minimum, but the weight and cost of the motor without axle bearings are much less than the axle bearing type of motor required with the conventional drive. The elimination of the axle bearings removes a source of oil leakage that is very difficulty to control. It also permits of much easier and quicker replacement in case of motor trouble.

Views "D", "E", and "F" show corresponding views of the conventional type of bridge drive as applied to mill type cranes. A comparison of the two types of drives reveals the following facts:

1. With the new drive the line shaft rotates at armature speed and transmits armature torque and consequently requires a much smaller diameter shaft. The conventional drive line shaft rotates at approximately ⅕ armature speed and transmits 5 times armature torque, and consequently requires a large diameter shaft. Since the armature speeds of mill type motors, such as are used on bridge drives, are in the 500 R.P.M. range, no trouble is experienced from this source. This statement is substantiated by a large number of successful installations in the field.

2. On account of the motor being located closer

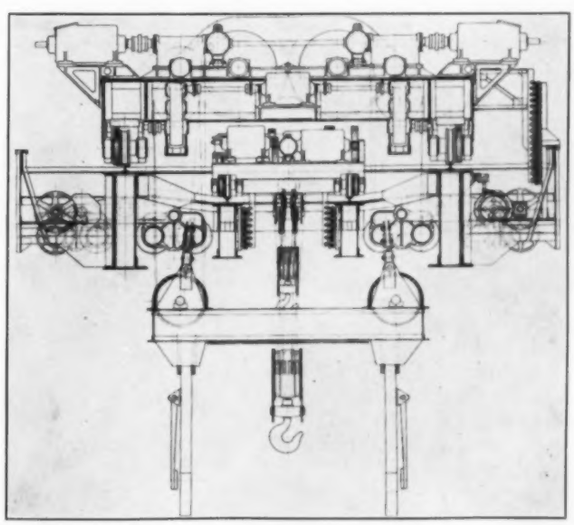


FIG. 4

to the crane girder than with the conventional drive, the overall width of the bridge structure is greatly reduced, allowing closer bridge approaches, and permits the crane to cover more floor space.

3. The omission of the axle bearings on the new drive reduces the cost of the bridge motor and removes one of the chief causes of the oil leakage and results in lower maintenance costs and easier replacements in case of motor breakdowns.

4. With the new drive all gears run in a bath of oil, in oil tight drip proof gear housings, resulting in quiet, smooth operation and long life of the gears.

5. With the new drive the torsional stresses produced by motor acceleration and motor or brake retardation, is reduced to a minimum and makes unnecessary the installation of outrigger girders.

6. The new bridge drive makes it possible to locate the comparatively small foot brakes on the end trucks and at the same time install the brake wheel on the low torque high speed armature extension shaft (or bridge line shaft).

With the conventional drive this arrangement is not possible as the line shaft has much greater torque, requiring much larger brakes to accomplish the same results as with the new type of drive.

The higher free running speed of the bridge motion, attained by the use of roller bearings, has made necessary the development of more dependable foot brakes, than the old mechanically operated type, which were universally used before the advent of the hydraulically operated foot brake. The mechanically operated brake with its multitude of levers, bell cranks, linkages, pins, and the twist of the operating shaft, provided sources of lost motion which became continually worse with service—the result being that if the brake were adjusted to produce an effective retarding torque, it would not release, and if adjusted to release, it would not produce any braking torque.

The hydraulic brake which inherently is free from lost motion, by virtue of the incompressibility of fluids, is the logical foot brake for bridge service, and is being specified almost exclusively by engineers.

The hydraulic brake is available in both the internal and external type.

Fig. #2 shows the internal type of brake. The outstanding feature of this brake is the assembly of the component parts. The outside diameter of the hub is machined, and mounted thereon are two antifriction bearings, which support the brake shoe mechanism. This brake can therefore be completely assembled in the machine shop, all adjustments made and the proper clearances between brake shoe and brake wheel made. The only work required in the field is to mount the complete assembly on the shaft, absolutely no adjustment being required in the field. Owing to the unique construction of this brake, any wear of the motor shaft or motor bearings will not effect its adjustment, owing to the fact that the position of the brake shoes relative to the brake wheel is maintained independently by the bearings on the hub of the brake wheel.

These brakes are easy to adjust and require few adjustments due to the fact that the braking surfaces are protected from grit and dirt and consequently do not wear rapidly. They are also accessible for easy repairs or replacement of parts and are easy to operate.

Fig. #3 shows the external type of hydraulic brake, which appeals to many operators, inasmuch as it resembles in construction and operation the old type of mechanically operated brake. These brakes are easily maintained, have few wearing parts, and are easily adjusted.

One of the main reasons for better brake service is the improvement in the materials from which the brake wheels are made. Many new iron alloys are now used for brake wheels, and we hear favorable reports as to their wearing qualities. Steel brake wheels with heat treated wearing surfaces are also available and are strongly advocated by operators who have had them in locations where the standard wheel did not give satisfaction.

In recent years heat treated gears and pinions have been specified almost exclusively and the result has been lower maintenance. There are those, however, who still prefer the .40 to .50 carbon untreated gear with shrink fit to the heat treated gear with press fit. The installation of gear guards which effectively keeps out grit and dirt, has done much to increase gear life and reduce maintenance to a minimum.

Worm gears are being used to an ever increasing extent and their popularity results from the very simple mechanical arrangement that obtains with their use. They are also quiet in operation and due to the selection of correct materials for both worm and gear and the high efficiency obtained with the proper contour of teeth, long life and low maintenance result. For ladle carnes having interlocked drums, the worm drive offers a mechanical arrangement unobtainable by any other means. Worm gears are always housed in oil tight cases which permit of the gears running in a bath of oil, and this undoubtedly accounts for freedom from mechanical trouble and their increasing popularity. Fig. 4 shows a typical worm driven, interlocked drum ladle trolley.

No part of the crane is subject to more abuse and more replacements than the hoisting rope. New types of reeving have been developed which greatly increase the life of the hoisting rope and provide greater safety. All of our ladle cranes built during the past few years have been equipped with the new reeving, and the results have been most gratifying.

Slight modifications of this reeving have been developed for standard cranes, and the same satisfactory results are being obtained in operation.

One of the most difficult parts of a crane to lubricate is the equalizer sheave or equalizer bar; the reason being that in normal operation the equalizer revolves only a few degrees. The introduction of the needles type bearing with its very small diameter rollers and a high load rating per square inch of projected area, seems to offer a very satisfactory solution to this problem. The few applications we have made have given most satisfactory service thus far.

Roller bearings on the whole have given very satisfactory service on crane applications. Most troubles are attributable to improper applications and incorrect rating data supplied to crane engineers. Recently roller bearings have been re-rated for crane service and the closer co-operation between crane builders and roller bearing manufacturers promises to eliminate the possibility of future misapplications. Most the roller bearing failures have been on bridge track wheels. This has been brought about chiefly by end thrust resulting from cranes twisting on the

runway. Instances of where the end thrust loading has exceeded the radial load have come under my observation. The introduction of the taper tread track wheel has done much to overcome this trouble, by eliminating crane twist.

Sealed bronze bearings and composition bearings are being used successfully and much development will take place in this type of bearing in the future.

These are but a few of the improvements that have been made during the past few years. Alloy steels are being used to an ever increasing extent and future cranes will be designed with greater amounts of alloy steel entering into their construction. These cranes will naturally be much lighter for a given capacity, and will require lighter runways.

Recently The Alliance Machine Company built a 300 ton crane for one of the large steel companies and alloy steel was used exclusively for the crane girders, resulting in lighter weight for the same strength.

At some future meeting we hope to deal in greater detail with the subject of alloy steel for cranes.

CRANE WHEELS

By J. C. KEEL
Mechanical Engineer, Bethlehem Steel Co., Steelton, Pa.

Rolled steel crane wheels are in general use, both as bridge and trolley wheels on practically all cranes coming under the maintenance of the electrical department at the Steelton Plant of the Bethlehem Steel Company. Two of the older cranes still have wheels of the cast steel center type with rolled steel rims shrunk on them. A goodly number of the trolleys are still using cast steel wheels, where the wheels are bushed and run on the axles, instead of being keyed to same. The rolled steel wheels are shrunk on the axles with a tolerance of about .001" per inch of shaft diameter—that is, the axles are turned full diameter and the wheels bored under diameter the proper allowance, and heated before the axle is placed in same. All track wheel gears are bored over diameter, placed on the axles and held in position with taper keys, these in turn being kept in place by using keeper keys, or retaining plates bolted to the end of the axle where the gear is overhung. Prior to the year 1930 all of our track wheels were of the straight tread type, but in the beginning of the above year the straight tread wheels on several of the cranes were replaced with taper tread wheels as drivers, and to show the advantage of taper over straight tread wheels, the following two examples are given.

Example No. 1—Cranes 120 and 121

Two 10 ton, 84 ft. 0 in. span, 320 F.P.M. traveling speed, four wheel drive scrap handling cranes were equipped with taper wheels in place of the straight tread wheels. These straight tread wheels had a life of about eight months, at the end of which time the flanges were so badly worn that they had to be removed and were replaced with taper tread wheels. These wheels have now been in service about four years and show very little wear on the flanges. The treads are becoming somewhat straight due to wear. Before putting tapered wheels on these cranes they would get out of line quite often, and it was necessary to run them to the end of the runway several times each day and bump them against the crane stops to straighten them up. The taper wheels have completely eliminated this fault. These cranes are equipped with roller bearings, and with the straight tread wheels, the end thrust was so great that it would grind off the ends of the axles when they would come into contact with the steel thrust pins with which the axle bearing housings were equipped. This trouble was also corrected by the use of the taper wheels. We also had two broken axles during the period when the straight wheels were in use.

Example No. 2

25 ton, 75 ft. 0 in. span, 180 F.P.M. traveling speed, two wheel drive rail loading crane having taper wheels as drivers and straight wheels as idlers. While these wheels have been in use about four years they show no wear on the flanges whatever. The treads have lost some of their original taper due to wear. The idler wheels show very little wear on the flanges for the above period. Before putting taper wheels on this crane, it was continually out of line. The taper wheels have eliminated this entirely.

On the above mentioned cranes, no change was made to the end trucks to accommodate the taper tread wheels, and for this reason the widths of treads are only 5/8" wider than the head of the rail on which the cranes run. With this small clearance it shows very plainly the advantage of the taper tread wheels. Cranes on which tapered tread wheels have been placed have end trucks which are of such design that the widths of the wheels could not be altered.

The welding of track wheels, so far, has not been very successful, due to the fact that the welded metal tears away from the parent metal after the track wheel has been in service for awhile as a driver. This does not show up so quickly when the wheel is used as an idler.

CRANE SAFETY

By R. F. GALE
Plant Engineer, The Midvale Company, Nicetown, Philadelphia, Pa.

The Association has done much toward making the electric traveling crane, in itself, a safe piece of apparatus. Little more can be accomplished in the design and physical improvement in the mechanism itself after a crane has been built according to the specifications of the Association of Iron and Steel Electrical Engineers. We can, therefore, consider for the moment, the chances of accident, having cranes equipped 100 per cent with safety features.

With all these physical improvements the electric crane should still be considered a very dangerous piece of apparatus unless properly operated and maintained. Regardless of the physical condition of an electric crane the safety of its operation depends

primarily upon the operators' ability and quick thinking. Different concerns have different ideas and organization, each to meet their particular needs. Some have a corps of regularly trained operators; others give little or no thought toward educating or limiting the number of men permitted to operate apparatus of this character. Operators of steam engines and elevators are required to have a license and we believe that this rule should be extended to all men operating electric traveling cranes, with more rigid requirements. Crane operators should pass physical examinations once every twelve months and if not included in a regularly trained corps of operators, should be properly educated as well as examined physically by those capable and be given some kind of yearly license, similar to a driver's license in the case of an automobile. New cards or licenses should be issued upon the result of annual physical examination and no person permitted to operate a crane unless he has on his person at the time such credentials.

The maintainence of an electric traveling crane can of course be carried far beyond real economy but never too far in an attempt to prevent accidents. Maintenance, outside of overcoming wear, should be extended to prevent abuses and the presence of any loose material or parts being left aboard, which material or parts may fall without warning, both of which a real, successful operator should be able to observe and prevent.

A common abuse to cranes is overloads, generally forced upon the maintaining department by the production departments and in many cases done without consulting maintainence department. After many bitter experiences, the overload slip, requiring thorough investigation and the taking of all possible precautions, is very often adopted by some concerns. Such a slip has to be executed for each and every overload and returned to the maintenance department files, constituting a very valuable reference to reliably investigate the cause of a physical failure which may subsequently occur. The collection of overload slips from a certain shop and certain crane also becomes a very valuable exhibit when that same department is in the market for, or feels a new crane is necessary.

Hoisting ropes and chains should be periodically inspected for any defects and replaced promptly when they are condemned. This inspection should be made by someone thoroughly familiar with hoisting apparatus, as the overlooking of a defect might result in a very serious accident. Some concerns use a written condemnation from which inspector's report is made out in duplicate, the original being issued to maintaining department to have the work done, the copy retained as a check until the original is returned noting the work has been completed.

In conclusion, let me say that no matter how good the crane design maybe or how many safety appliances are installed thereon, accidents will creep in if the human element is permitted to lax in the operation and maintainence of the crane.

ANTI-FRICTION BEARINGS FOR CRANES

By A. J. STANDING
Electrical Supt., Bethlehem Steel Company, Bethlehem, Pa.

Having been asked to discuss Mr. Harry's paper from the standpoint of anti-friction bearings and not having seen the paper, I feel free to express my own thoughts on this subject.

To many of us the use of anti-friction bearings on cranes today is so inseparably a part of good crane design that I scarcely feel the necessity of attempting to justify our stand, and yet we all realize that there are questions and doubts in the minds of many potential crane users that can only be answered by experience gathered from the general body of crane users.

The advantages of anti-friction bearings when properly applied to crane design are manifold and the disadvantages so negligible as to be of no moment when we base our judgment on right conditions.

Citing some of the advantages of anti-friction bearings when properly applied to cranes, we might touch on the following:

1. Possible reduction in motor sizes due to reduced friction load with consequent saving in first cost of motors and controllers, as well as, continued saving in power costs.
2. Reduction in maintenance cost.
3. Reduction in delays.
4. Economy of lubrication, both as to time and lubricants.
5. General elimination of dripping oil and grease on the floor or on the product. The latter feature being of great importance in tin and plate mill operation.

In order to balance the foregoing advantages, the only real cause for complaint has been the failure of roller bearings in bridge track wheels to stand up under severe end thrust and this condition is so evidently one of faulty design aggravated by poor runway condition that I hardly feel it can rightly be classified under the heading of a disadvantage inherent in the bearings themselves.

By way of establishing our background in discussing this subject I will give a resume of our somewhat limited experience in the Bethlehem Plant, but I can also state that we are very much sold on the performance of these cranes and look to future applications without the slightest misgivings.

Anti-Friction Bearing Cranes at Bethlehem

150-Ton Morgan Ladle Crane, completely equipped with Hyatt roller bearings.

This crane was put in service in 1926 and has had possibly 80-90% service with only one case of bearing trouble, and that was due to a loose inner race which was taken care of and no trouble experienced since.

3—200-Ton Morgan Ladle Cranes, completely equipped with roller bearings and worm drives, were put in service in 1930. The only trouble experienced was in connection with bridge speeds and one thrust

bearing failure in a worm drive, due to lack of lubrication, caused by a defective grease fitting.

These cranes have had varying service, from 75 or 80% to about 50% of normal, during the past four years.

First crane, No. 5531, poured heat from #42 furnace, January 30, 1931, at 5:30 P. M.

1—20-Ton Alliance Crane, in steel foundry service. This crane is equipped with roller bearings on bridge track wheels only and has been in service since 1925, with no delays due to bridge bearings to date. At the time this crane was installed, roller bearings were used as an expedient to secure greater end clearances and trolley bearings were not considered. Bridge bearings were so designed as to be replaceable with MCB bearings if necessary.

In discussing roller bearings applied to cranes, so much depends on the proper applications being made that we feel it is of the utmost importance that the bearing engineers and crane design engineers get together and decide on the best possible application and installation regardless of old ideas and patterns of the sleeve bearing era. If a radical departure in crane design is necessary in order that the customer may enjoy all the advantages possible with the use of anti-friction bearings, then by all means make the changes which will bring about the best results.

We realize there is a certain design inertia to be overcome in all developments, this has been best illustrated in connection with welded designs which too often strive to make the welded job look like the casting we have been accustomed to seeing.

Applications—Bridges

The first essential consideration must be given to load bearing characteristics of the proposed roller bearings, whether straight or tapered, and when this is known, the proper size bearing must be selected to safely carry this load with a good margin of safety. In this connection it may be well to stress the importance of selecting bearings for the heaviest corner of the crane; namely, the cage corner where the load due to cages and magnetic control produces a very appreciable increase in track wheel bearing duty. It is then, of course, wise to use the same size bearings on all bridge wheels from a consideration of the value of standardization of parts.

The main cause of failure of bridge track wheel bearings that has come to the writer's attention is that of end thrust and in several cases, particularly of cranes on old runways, this has proved to be of such consequence in some instances as to necessitate the replacement of straight bearings with tapered bearings, in other cases the provision of special steel or bronze wearing plates to take care of thrust and in still other cases the replacement of washers with ball races to take end thrust.

I have not heard of any case where this trouble could not be properly taken care of. In general the separation of the load bearing and thrust features of a bearing is the wisest design.

Bridge Speeds

The subject of safe and economical bridge operating speeds requires a careful revision in the light of anti-friction bearings.

Bridge drive motors must be carefully selected as to size and load with the result that it may be found desirable to use smaller compound wound motors or two series motors operating in series. The selection of proper gear ratios is of extreme importance and has a very direct relation to motor sizes and speeds.

The 200-ton ladle cranes cited before were specified to operate at 250′/min. at light load, using two "GW", 110 H.P. series motors in parallel on the bridge drive. These cranes actually ran at 510′/min. and would have gone considerably faster if we had allowed them to continue to run freely.

We first changed to compound wound motors and finally back to the operation of both motors in series with a free running speed of 310′/min. which we all feel is about the most economical speed for our use.

The load test of the two bridge motors operating in series showed 400 amperes starting and 200 amperes running at 300′/min. which was about 600 R.P.M. of the armature.

Inseparably connected with the discussion of bridge speeds is the subject of bridge brakes, and these may be as varied as the designers' and the purchasers' opinions dictate, in the light of their experience.

The cranes at Bethlehem are equipped with a very powerful foot-operated bridge brake, which has proven entirely satisfactory for our service speeds. I have been advised that in some instances there have been air brakes and even electrical brakes applied to bridges.

By way of additional interest, I might cite the two following crane installations where the bridge speeds were allowed to remain rather high for the size cranes involved. I believe that in the case of the 175-ton cranes there has been some bridge foot brake trouble.

1—200-ton, 59′ span, Morgan ladle crane, roller bearings. 2—80-MC, 110 H.P. motors in parallel on the bridge drive.

Speed, light—475-480′/min.
Motor speed—960-1000 R.P.M.
Current per motor—100 ampere.
About ¼ load.

3—175-ton Alliance cranes (1928).

Bridge speeds up to 600′/min.

Use ball bearings to take bridge thrust in place of bronze thrust washers.

Worm drives—O.K.

Suggest air brakes in place of foot brakes for future cranes.

Trolleys

The application of anti-friction bearings to trolley drives requires the same study and deliberation called for in bridge drive applications with this one additional thought, that in the case of very light trolleys the use of anti-friction bearings may permit of excessive drifting of the trolley which may in a measure offset the advantages to be gained by the use of smaller motors, ease of lubrication and other normally present advantages of anti-friction bearings.

In many cases brakes have been added and while these help to spot the trolley and prevent drifting, they in themselves constitute one more item of first cost, as well as maintenance cost.

In the case of heavy duty crane trolleys, I feel there is no question as to the advantages to be gained by the complete use of roller bearings.

The other motions, as hoists, sheaves, blocks, etc., can all be very materially improved by the careful application of the proper type of bearing for each service.

Lubrication

Theoretically a high grade, fairly light oil is generally accepted as the ideal lubricant for roller bearings, but due to the difficulty of properly handling such a lubricant in crane bearings, it has become general practice to use a light, so-called, roller bearing grease, which can be readily held in the bearings by means of felt washers and kept fairly free from the infiltration of mill dust and dirt, the presence of which would be most detrimental to the bearings.

Much has been written regarding types of lubricants and particularly frequency of lubrication, but I think it can all be covered by the general recommendation of a reasonably good grade of grease applied as experience indicates, it to be necessary, depending on the operating conditions. Our bridge track wheel bearings require attention once a month, whereas, the bearings in a frequently reversing crane motor may require attention more frequently. I think it is useless to attempt to set up hard and fast rules of lubrication which may only result in trouble for someone who may take them seriously.

In as much as I am not writing a paper on anti friction bearings, but rather discussing a definite feature of crane design, I will close my discussion with a statement of my very sincere belief that proper applications of anti-friction bearings will in all cases prove beneficial to crane service.

CRANE CONTROL

By H. H. ANGEL
Electrical Dept., Bethlehem Steel Company, Sparrows Point, Md.

The control equipment on an electrically operated crane must provide the utmost in safety and reliability. The improvements in crane control during the past ten years have kept pace with crane developments.

Most steel mill electrical men now realize the advantages of magnetic control over manual control when applied even to the moderate duty cranes. The present day master controllers lend themselves to a very practical arrangement in a crane cab, and allow faster operation with less fatigue to the operator. The crane cab will be safer for the operator as the control panels may be mounted in the operating cab at a safe distance from the operator, or may be enclosed if necessary. They may also be mounted in a special cab, on bridge foot-walks, or in any other desirable location.

On light duty, low capacity cranes, the manual controller will give good performance and the extra 50% to 150% first cost of magnetic control may hardly be justified. However, when the motors are above 50 H.P., we have found that crane operators, in order to move bulky drum or face plate controllers without undue fatigue, will loosen the face plate brushes and drum controller fingers to decrease the friction. This results in a loosely operated controller without a substantial centering position and consequent high maintenance.

On heavy duty cranes, the greater first cost of magnetic control will be offset in some cases within a year by the decrease in maintenance of the control as well as the lesser wear and tear on the motor, gearing, line shafting and bearings due to the limiting of the accelerating and plugging peaks. In instances where a crane has been over motored, the motors are better able to withstand the abuse from hand controlled excessive current peaks than the mechanical parts of the cranes.

We have found the modern small size vertical drive master switch to be superior to its bevel gear type predecessor. The segment and finger construction is better and the pins and bevel gears, which have always had considerable looseness from wear, have been eliminated. In some cases, however, where more than four or five points are necessary for special hoist controls, the smaller type is not suitable.

There has been much discussion on proper crane protective equipment. Some prefer the overload relays on the individual motor control panels with an enclosed knife switch or circuit breaker in the operating cab. Others use a protective panel consisting of a line switch, two line contactors, and one to two overload relays per motor. We have always preferred control panels without overload relays, line and control switches. The protective panel consists of a main line knife switch, one circuit breaker contactor in the positive circuit of our grounded negative system, control switches and one overload relay per motor. In some cases, two motors are protected by one relay. We have found it better to maintain a fewer number of relays in good condition than to have a larger number with some inoperative. Due to the abuse some of the cranes receive, we have found overload relays do not serve as protection against the usual overload. They protect against very excessive overloads, short circuits and grounds.

We have always connected our starting resistance in series with the positive side of the line ahead of the motor. When a grounded mica ring or armature occurs during acceleration, the magnitude of the current depends upon the amount of resistance in the circuit. The instantaneous tripping of the overload relay, provided the current flowing through the ground is high enough for the setting, will prevent an excessive amount of damage to the commutator or the laminations. During the last four years we have been using a substantial type of inverse time limit overload relay on our cranes and have found same can be set at a lower current value than the instantaneous type. This means it will not operate during unusual starting current peaks but will trip when a condition exists such as say 150% continuous overload or 150% full load current from a grounded armature which has some starting resistance in the circuit at that particular instant.

The hoist of the present day crane does not employ a load brake. This means a dependable type of dynamic braking control is used, with the high speed lowering feature a very desirable one. It is now pos-

sible to safely obtain a light hook lowering speed of around 175%-200% of full load hoisting speed. We have always favored such a control as simple as possible and with a minimum of relays. All dynamic braking controls are quite complicated when compared to the simple reversing bridge or trolley control, and consequently the simpler it is, the easier for the average electrician to locate trouble.

The average bridge control is comparatively simple. Roller bearing cranes require one extra accelerating contactor and additional starting and plugging resistance. We have found that for duplex drives on ladle cranes, where the motors operate in parallel, best results are obtained with separate reversing, plugging and accelerating contactors per motor. For a 150 Ton sleeve bearing ladle crane, one plugging and four accelerating contactors per motor seems to be sufficient.

We also have several cranes where only one set of plugging and accelerating relays is used for the above contactors. A double throw control switch is used to connect the relay coils to either set of resistors. When both motors are operating, the switch may be thrown in either position, but when one motor is cut out, the switch is thrown to operate from the motor in service.

We also have a heavy duty soaking pit crane bridge with duplex drive controlled by a panel with double pole contactors. This panel is smaller than those described above, is far simpler, and has proved highly satisfactory.

CRANE MOTORS AND GEARS

By G. C. PFEFFER
Electrical Engineer, Florence Pipe Foundry & Machine Co., Florence, N. J.

It is the aim of the speaker by this discussion of Mr. Harry's very complete paper, to bring out some points that will be of material assistance to the prospective crane purchaser in obtaining a crane equipped with the proper size of motors and gear ratio for his particular service and conditions.

The questions usually asked by the crane builder's representative when he calls upon the prospective customer are somewhat as follows:

What hoist speed do you desire?

What is the maximum load to be lifted?

What is the maximum lift in feet?

For the bridge and trolley motion he asks:

What speeds do your desire, and the total travel of each motion?

With this information the crane builder proceeds to determine the size of motor and gear ratios.

No mention is made of the duty cycle, which item is unquestionably the most important of all in determining the proper size of motor and gear ratios. It is hoped that at some future time this question of duty cycle will be added to the standard crane specifications of the A. I. & S. E. E.

At the meeting held by this section in April, 1932, the speaker had the privilege of reading a paper entitled "Short Cuts on Crane Maintenance." In this paper were shown the economies effected by a change made in gear ratios on a crane in a production shop. The economies effected by the change were $3,500.00 per year. This item is mentioned merely to call to your attention the need for giving the subject—duty cycle and gear ratio—the proper consideration.

Another point seldom stressed by the crane builders is the matter of high grade gears—let them be hardened steel, carburized, or any other name you wish—a good gear pays big dividends, the dividend being directly proportioned to the quality of the gear.

While delving through the 1920 proceedings of the A. I. & S. E. E., the speaker came across a paper given by a Mr. Gordon Fox, a fellowmember of this Association. This paper was entitled "Auxiliary Drives." Mr. Fox in this paper also stresses the need for considering duty cycle and gear ratios.

In addition to the above mentioned items, relative to gears there is one other item that should be borne in mind, and that is, all gears should be of a standard cut and should be, as far as possible, interchangeable. This last item is very important, as it is a means of cutting down storehouse spare parts stock.

With the advancement made in recent years in the manufacture of worm gear speed reducers, it is thought that this type of speed reducer could be applied advantageously to cranes, in lieu of spur gearing. This is especially true of the trolley motion on foundry cranes.

In the plant in which the speaker is employed, considerable trouble has been experienced in lowering long cores vertically into moulds, where the clearance between the core and mould was very slight. With spur gearing, after the numerous bearings and gears become worn, sufficient movement developed in the trolley to permit the core to strike the mould. Brakes were applied to this motion but unless they were applied to the wheel shaft of the trolley they did not prove very effective.

Worm gearing, with its fewer bearings and its characteristics, could no doubt be applied very effectively to a case of this kind.

Some of the crane builders have built cranes using worm gear reductions. It would be very interesting to learn the results obtained from their use.

In closing, it is hoped that this brief paper may serve its purpose in assisting all concerned to bring about a crane construction comparable to some of the other highly efficient equipment used in the iron and steel industry.

CRANE CONTROL

By W. R. YORKEY
Engineer, The Electric Controller & Mfg. Co., New York, N. Y.

Mr. Harry and other speakers here this evening have brought out the fact that unusually high bridge speeds are encountered on modern anti-friction bearing cranes, and that the bridge brakes now in use do not seem to be all they should be.

It may interest the members to know that equipment has been developed which will give emergency dynamic braking on the bridge drive of such cranes and which can be applied as a safety measure in case the regular brakes are insufficient or in the event of power failure when plugging.

Since series wound motors are practically always

used, it is necessary to employ a system of control properly designed to give dynamic braking in both directions of rotation. On first thought, it might seem that this equipment could be operated from contacts on the master switch, but this is not possible, since the master might be in the reverse position with the crane still going forward at the instant of power failure.

A directional switch is therefore employed, which closes either one set of contacts or another depending on the rotation of the bridge motor, and in this way, the proper connections are established to obtain dynamic braking in both directions of travel regardless of the position of the master switch.

This equipment has been developed for both single motor bridge drive and for two motor bridge drive.

It is also possible by the addition of a simple foot operated push button located in the cab of the crane to use this same device for service braking if desired.

There is another development, which we as manufacturers of brakes have been glad to see and that is an increasing use of magnetic brakes instead of mechanical brakes on the bridge drive of ordinary cranes. Both shunt and series brakes have been used. They are usually set for decreased torque. The shunt brakes can be operated either from a foot push button or the controller. The series brakes are operated from the controller and in either case, a drift point can be provided.

In applying brakes to the bridge drive of cranes, it is advisable to check up on the heat radiating capacity of the braking parts. This is not usually done on hoist applications but may be important on a hard-worked heavy crane where the motion of a large mass is being stopped, particularly if the crane is equipped with anti-friction bearings.

Brakes are occasionally applied to trolley drives, and if a series brake is used particularly on trolleys equipped with anti-friction bearings, the no load motor load should be checked to be sure that the brake will not set.

One of the speakers this evening has pointed out the necessity of co-operation between the mechanical and electrical manufacturers to obtain the best installation and I want to add a plea that the mechanical man bear the electrical man in mind in making his design. We recently had a case on an ingot buggy where the actual load was 6 H.P. but in order to hold to motor standardization of the mill, the manufacturer used a 40 H.P. motor. To hold the speed of the ingot buggy to a reasonable figure, we had to operate the motor under permanent armature shunt. At the end of the travel the motor would not develop enough torque to tip the ingot and this necessitated additional limit switches which first removed the armature shunt at the end of travel to tip the ingot and then re-applied it to slow down. This could have been avoided and a simpler control used if the manufacturer had used a motor size closer to the actual load.

CRANE WHEELS

By E. S. SAWTELLE
Vice President, The Tool Steel Gear & Pinion Company, Cincinnati, Ohio

I consider that the Association owes a debt of gratitude to Mr. Harry for being one of the early aggressive proponents of the taper tread idea for crane wheels. We have made many of them and have found that they have cured many evils. I have known in cases where the flanges were literally being pressed sidewise off the wheels, taper tread was substituted and actually rust would be found on the flanges of the taper tread wheels. A most interesting demonstration is to take a crane with plain tread, bump it crooked on the rails and watch the wheel action as they climb and bind all the way up and down the track. Then take a crane with taper tread wheels, bump it crooked and watch the action as it skews itself around and straightens itself without severe flange pressures. By the time it has traveled half way down the shop it centralized. One very important factor is to have sufficient width between the flanges to give proper chance for the taper tread action. A second thing of great importance is to have the tread of the wheels extremely hard and durable so they remain taper tread for the longest possible period of time.

Mention was made of brakewheels hardened; we have found that with an extremely hard wheel a tremendous saving was encountered in brake linings, often a saving greater than even the saving through long life of the wheel itself. Safety has been stressed in the discussion; certainly the use of better materials with less frequent changes, whether in gears, wheels, brakewheels, or what not, decidedly curtails the frequency of renewals and the chances for accidents when renewals are made under adverse conditions.

MAINTENANCE CRANE BRIDGES AND TROLLEYS

By F. D. EGAN
Electrical Supt., Bethlehem Steel Company, Lackawanna, N. Y.

The first consideration in maintenance of electric overhead traveling crane bridges is the provision of a suitable runway. Much of the trouble in crane bridges, originates with poor runways. In all cases where possible runways should be supported on ample foundation and tied together across the top to maintain correct span. In instances on yard or open runways, where it is impossible to provide a tie across the top, more consideration must be given to obtaining rigidity in upright supports. The crane rail on runway must be of suitable section to carry required wheel load and rail joints maintained in good shape to prevent shock and bumping. The concentrated wheel load should be kept at a safe value and where necessary on heavy, long span cranes, compensating trucks be utilized to keep down wheel load.

The type of construction employed in building

the crane bridge is a big factor in determining the amount of maintenance required to keep it in shape. We favor box section girders, seated on machined surfaces on cast end carriages with heavy gusset plates and rugged end ties consisting of a plate on edge bolted to machined surface on end carriages and riveted to ends of girders. This end plate is backed up on top with heavy angle and gusset plate tied into top cover plates of girders. We also favor a structural auxiliary or outrigger girder on the bridge drive side of the crane to support bridge motor, lineshaft, and cage without undue turning moment from this weight on the main girder. The outrigger girder is carried either on projected castings on the end truck or when this is not feasible on main end ties extended. The pedestal bearing and foot-walk supports, as well as bridge motor support are all tied into main and auxiliary girder and forms a rigid construction for supporting the weight involved.

The trolley construction is largely governed by the type of service for which it is to be used. Where possible, we prefer cast trolley frames and in all cases require long through shafts with a bearing on each trolley frame. Structural motor supports and lifting beams should be supported on shear pads on trolley frame casting, so as not to place holding bolts or rivets in tension.

In order to keep down trackwheel maintenance, we use rolled steel wheel blanks, heated and oil quenched, for bridges and trolleys, which gives a tough wheel and materially increases the wheel life. We are in a position to provide this treatment in our own maintenance shop.

Reversing and plugging control for both trolley and bridge service should be arranged and maintained for soft acceleration and moderate plugging. This should be accomplished automatically in the control and be out of the hands of the operator. Severe racking stresses through forced acceleration and plugging result in much of the trouble experienced in broken lineshafts, couplings, gearing as well as loose connections in structural members.

TRACK WHEELS–RAILS–BUMPERS

By J. A. BURG
Mechanical Engineer, Carnegie Steel Company, Homestead, Pa.

Track wheels and rails are important items in crane maintenance, especially when trouble is experienced with them. On numerous cranes the service obtained from the wheels is very good. Length of service of from 10 to 15 years is not unusual for track wheels on many cranes. Yet in other cases, the life of the wheel may be comparatively short and the maintenance cost high.

Track wheel trouble may be ascribed to a number of causes. Older cranes in many cases have been rebuilt and their capacity increased without making any alterations to the wheels, axles, or rails. The cranes may be overloaded severely, the wheels may wear unevenly, the trucks, or the track may be out of alignment, or the runway may not be level. If the track is slippery in spots, the crane may get into a twist and cause excessive flange wear. In our experience wheels having their tread radiused to conform to the rail head invariably have given trouble until the tread was made flat or tapered.

The use of wide tapered tread rim-toughened rolled steel wheels will eliminate much of the trouble experienced. These wheels have a very hard tread and consequently longer life with less wear. They also permit the use of higher wheel loads. If made with tapered tread, the flange wear is practically eliminated and the thrust on the track wheel bearings is reduced. Even for trolleys, the use of tapered tread wheels on the drivers has proved of advantage.

Our practice is to shrink all wheels on the axles. We have never had a wheel shrunk on to come loose. The practice of keying the wheel to the axle could be eliminated by shrinking the wheel on. The keyway is a weak place in the wheel and often is the starting place for a crack which finally results in the breaking of the wheel. We have in use some heavily loaded wheels shrunk on axles without keys, which are giving very good service.

If flat tread wheels are used, they must wear evenly or else the crane will tend to twist and cause excessive flange wear. In some cases where the flange wear is a factor due to misalignment of the runway, we have found that by leaving the rail clamps along one runway loose enough to permit the rail to shift sideways ½", we obtain fairly good results. With tapered treads the rails should not be permitted to move sideways.

The foreman can be of great assistance in keeping down maintenance costs, by seeing that the crane is kept in alignment and that the trucks and end braces are properly held in place. Axle brasses or other types of track wheel bearings must be carefully and regularly inspected.

If the runways are neglected, trouble may still be expected. The levels and alignment must be kept reasonably good. Rails should be ample in size to carry the loads without undue wear. Rail joints must be kept closed, otherwise the hammering sustained as the crane passes over these open joints may have serious effects on the entire crane. This hammering also flattens out the rails at the joints and may cause flat spots on the wheels. This trouble can be eliminated by welding all rail joints. Welding today has progressed to a point where this can be done very successfully with the use of manganese steel rods. If the rails are welded by a softer rod and then the manganese used on the top, a successful weld that will hold up can be obtained. As regards expansion, or contraction, this should be practically the same as that of the runway.

Some welding of rails to cover plates has been done. Our experience along this line has not been satisfactory. Difficulty is encountered when welding the high carbon rail to low carbon plates. Frequently the weld breaks loose. We prefer rail clamps.

On the older cranes, we find the rails wearing into the cover plates; in some cases as much as 3/16" or 1/4". In such cases another plate about 3/8" or 1/2" thick, of a width to fit between the flange angle rivets is put on the cover plate and stitch welded to it. To avoid this cutting of the main cover plate, we now specify that the girders be

equipped with a wearing strip under the rails, which can be easily replaced when worn.

It is very important that rails, wheels and axles be sufficiently large to carry the loads without undue wear. We had a case of trouble on two of our hot metal cranes which was solved in a very gratifying manner. These cranes operate in an open hearth department containing a metal mixer and its brasses and axles are naturally subjected to the action of particles of iron oxide. Enclosing the bearings did not help us. About three years ago, we changed wheels and installed three new ordinary forged axles and one of nitrided steel, together with new axle brasses. Recently we changed wheels again because the brasses and axles showed considerable wear. We were surprised, however, to find that the nitrided pin showed practically no wear and had acquired a very high polish while the brasses on it also showed practically no wear. This crane had not operated very much during the three years, yet the three ordinary axles and brasses were very badly worn. We immediately replaced the three axles with nitrided steel axles and new brasses and installed them together with the original axle and its brasses. This has reduced our maintenance cost greatly and because of the high polish these axles acquire, the friction was cut down considerably. Tests showed a 16% increase in speed and 36% saving in power with four of the eight axles of nitrided steel. We are equipping the follower wheels with nitrided axles and this will undoubtedly result in an additional increase in speed and a further reduction in power requirements.

As regards bumpers, the best way to avoid high maintenance costs on them is not to hit them. But, this is obviously impracticable. Bumpers should always be of the spring type. The use of spring bumpers bolted to the girders and engaging stops on the sides of the trolley permit the maximum approaches. All bumper plungers should be loosely chained or cabled, so that they cannot fall in case the bumper stem should break, or the nut come off. Often bumper stems are turned down on the end and threaded for a nut. This makes a weak place and the stem often breaks at the shoulder where the threading starts. By increasing the threaded section diameter to that of the rest of the stem, this trouble is often eliminated. Sometimes, however, it is necessary to increase the entire stem diameter. By keying the bumper castings against a shoulder, the bolts or rivets are relieved of considerable strain. Welding the castings to the cover plate also has helped.

Main runway bumpers should be substantially built and solidly attached to the runway to prevent uplift. The engaging bumpers on the crane bridges should always be of the spring type.

The proper time to consider maintenance on a crane is when it is being designed and built. The mill type crane of today is considerably heavier and more substantial than the older cranes. The purchaser is more familiar than the builder, with the requirements to be met. He should carefully check wheel sizes, see that the rails are heavy enough to meet the loads and keep the bearing pressures on the axle bearings reasonably low. Wide tread, rim toughened rolled steel wheels with tapered treads should be used on all driving track wheels. Follower wheels may be flat tread, if so desired. Rolled steel gears running in oil tight housings will give longer life and lower maintenance.

On our bridge drives we have adopted a construction which is giving much satisfaction. We use either one gear box at the motor, or one near each end of the bridge. These gear boxes are oil-tight. The driver wheels are coupled to the gear boxes by means of flexible couplings which take care of the axle bearing wear. This construction makes a simple truck design and a simple track wheel assembly without gears, which on the older types are very difficult to enclose properly. By the use of the gear boxes, it is possible to use shorter axles and in addition, to obtain symmetrical loading.

Other points to be considered carefully, especially on the heavier cranes, are the number of wheels to be used and the number of these to be drivers. These directly affect maintenance to a considerable extent. Such questions come up when the wheel loads approach 70,000 to 90,000 lbs. There is no doubt that with the better runway construction today and the use of both heavier rails and rim toughened wheels, it is possible to operate satisfactorily under these loads without trouble. If our loads can be handled on half the number of wheels without exceeding the above figures—why add extra wheels? The change from a four wheel crane to an eight wheel crane means a considerable increase in parts to be looked after. In many cases, especially on inside cranes having eight wheels, it is customary to drive four of these. Our experience has shown that it is possible to operate satisfactorily by driving only two wheels on many cranes. An outstanding example of this was the case of our 275-ton roll crane, originally designed and built with 16 wheels, double bridge drive with 8 of the 16 wheels as drivers. We removed the idler pinions and tried driving with only four wheels and the crane operated very nicely. Thus, we eliminated four drivers, the idler pinions and facilitated the changing of drivers at any future time, as they are now the outside wheels of the four outside trucks.

Crane builders can be of great assistance in helping reduce maintenance costs by making all like parts interchangeable whether they are on one crane or more than one. Standardization of parts where possible cuts down the spares required. It is quite discouraging to attempt to interchange parts which should be alike and find the drilling out a little, or the machining different. Close inspection and careful assembling will prevent trouble later on. Co-operation between the purchaser and builder and a thorough study of all factors applying to the crane being bought will go far toward providing a satisfactory job of low maintenance cost.

CRANE RAILS

By G. R. CARROLL
Electrical Supt., Jones & Laughlin Steel Corp., Aliquippa, Pa.

I will confine my remarks to the fastening of the main rails to the runway girder. I think in practically all of our papers on the discussion of cranes the last few years that this particular subject has been very much neglected. We have increased the

speed of the cranes, made them heavier and have changed to anti-friction bearings, and most of us use the same old methods of fastening the main rails. The type of rail construction has an important bearing on maintenance cost, both from a wheel and rail standpoint.

The methods that have been followed in the past, with respect to rails, seem to resolve themselves into two general classes: In one the designer had the idea of fastening the rail rigidly to the runway girder. Such a method does not work out so well because they invariably become loose. In the other class the rail was so installed as to be free to move and there were a good many ways devised to accomplish this result. But all of these methods—and I think all of the maintenance men will agree with me—tend to result in the rail becoming crooked in time. This condition results in excessive rail wear and does not help the wheel problem.

If we look to the railroad engineers, who possibly know more about rails than we do, and who have had more experience at least, I think we will find that they have three important factors to consider when laying their rails.

(1) Building into the rail support some resiliency. I have talked to railroad engineers about this and they have stated that the method of supporting a rail directly on a foundation similar to a continuous beam does not serve the purpose. They have tried to use steel ties and that has not worked out so well. Even on steel bridges the wood ties have been found to give the best results.

(2) Another factor that they are very careful about is keeping the rails straight and parallel with one another. Their problem in this respect, of course, is much simpler than ours.

(3) The other factor is the coefficient of expansion of the rail compared to that of its foundation. I believe this is one of the principles most often neglected when building crane runways. Both the rails and the building on which they are supported have definite coefficients of expansion from temperature changes. They are not equal to one another by any means. Therefore, we should build our crane runways in such a manner as to allow for this difference and still keep a straight rail.

The method I wish to submit for your consideration is one that has been tried out in one or two instances and works successfully. It is a little more expensive but I believe it saves maintenance expense in the long run. Instead of laying the rail directly onto the girder and fastening it down, we take the standard tie plates used in railroad construction, weld them onto the runway girder on about 18" centers, in proper alignment and then lay the rail on these tie plates. Suitable clips are then used to prevent the rail from turning over or getting outside the tie plates. These clips do not restrain the rail from having free movement lengthwise. The runways I have in mind have been in use for two or three years and are still as straight as ever. The crane service has been severe and at fairly high speeds. I might add that tapered tread wheels are being used to an advantage on these runways. It would be interesting to hear some criticism and discussion on this method that has been outlined.

BEARINGS, LUBRICATION, GEARS AND PINIONS, SHAFTING

By J. FARRINGTON
Electrical Supt., Wheeling Steel Corporation, Steubenville, Ohio

Many of the bearings in the early cranes were cast iron, that is the shafts ran through the cast iron trolley sides. This was a fairly good bearing until it wore or the shaft became bent then it was a different story.

The next step was to core the casting and babbitt the bearing, this was an improvement but required considerable time and expense to babbitt a bearing up in the air.

The next improvement was the use of brass bearings or sleeves which were not always machined, but when machined made it very easy to change on the crane.

The cast iron shell, babbitt lined was and is extensively used especially for large bearings. They give excellent service and are easily and economically replaced.

The most recent improvement is the use of anti-friction bearings which greatly reduce the friction load and in most applications give a long life, with very little wear thus keeping gears and pinions better in mesh resulting in longer life to them.

When anti-friction bearings are used on the bridge trackwheels, the crane runway must be kept straight and in good condition to avoid trouble.

We have experienced considerable trouble with anti-friction bearings on bridge trackwheels due to end thrust and the use of too small a bearing by the crane manufacturer.

On several of our cranes we have used a full floating bronze bushing in the bridge trackwheels, the bushing being free to turn in the wheel or on the pin, the pin being held fast by caps for easy removal.

The friction load being so small the crane will coast very nearly as far as one equipped with anti-friction bearings.

Many of these bearings have lasted for more than five years.

Another type of bearing that we are using is made of cloth and a filler compound put in under pressure. We have used one make of this type of bearing on a bridge line shaft on a mixer crane and after seven months service showed only .008 of an inch wear and had not scored the shaft.

We greased the bearing when installed but did not use any more grease after that.

We intend to experiment further with this type of bearing as we believe it offers a relief for many of our lubricating troubles.

Lubrication

Most bearings require lubrication of some kind, and where the craneman has time to properly grease the crane we believe good results can be obtained by the use of fittings and a hand grease gun, as this allows the craneman to inspect the crane at the same time.

Where the craneman has not the time to properly

grease the crane a central greasing system offers a sure and quick way to apply the grease.

On worm drives where the tooth pressure is high we have found relief by using "Leadolene".

On one application of worm drive on the hoist of a soaking pit crane the tooth pressure is so high that we have had to install a small motor driven oil pump to apply an oil stream on to the worm.

We study the conditions and then use the lubricant best suited for those conditions, we believe no lubricant has all the best qualifications.

Gears and Pinions

Gears and pinions wherever possible should be cut and heat treated and run in oil tight gear cases.

They should be thoroughly inspected every so often to see that they are properly in mesh, and if not, renew the bearings, bringing the gear and pinion to the proper mesh to prevent excessive wear.

Worm drives are being extensively used but they should be selected with great care to see that they are large enough for the work required of them, especially if the teeth are always in pressure and the worm gear makes but a part or few revolutions as the lubricant will be pressed from the teeth and not replaced.

When herringbone gears are used they should be of the double type to prevent end thrust, especially if the bearings are of the anti-friction type.

Shafts

On all important applications such as ladle, stripper and pit cranes, the shafts should be of alloy steel treated and ground to true diameter.

Not only will they give a greater factor of safety but will reduce the friction in the bearings and wear longer.

Bearings should be used wherever bending takes place in the shaft to prevent breakage as this condition is overlooked by some of the crane builders.

Shafts that have but a slight motion such as are used in compensating end trucks and equalizers, should be provided for oil lubrication, not grease, as the oil will not harden and prevent flow of lubricant.

All shafts that are threaded into position should be provided with means to enter and withdraw them.

GENERAL MAINTENANCE

By C. W. UPTON
Maintenance Dept., Bethlehem Steel Company, Johnstown, Pa.

(1) My discussion is listed under the heading: Bearings, Lubrication, Gears, Pinions and Shafting. Rather than discuss any one of these topics in particular, my remarks will be more in the way of general discussion in which all of these topics are in some way involved.

(2) We have eliminated the use of cast iron gears and most cast steel gears and are using a product of our plant, rolled steel gears either untreated, treated or case hardened. In most cases the gears are untreated, 40-50 carbon steel, bored for a shrink fit. We get excellent service from the gears and very few shafts are ruined because of loose fits. Where bevel gears are involved, heat treated or case hardened gears are used generally and a shrink fit is not employed. Regardless however, of what is used and aside from the standpoint of safety, all gears should be kept lubricated and covered with guards. The guards will pay for themselves many times over by increasing the life of the gears. We realized this very conclusively because we were operating some old pit cranes in the open hearth without gear covers. The design of the cranes was such that the gears were very hard to cover. However, we made a drive which stopped only after all gears were guarded and in addition to eliminating accident hazards, we get much longer life from the gears.

(3) Recently we have taken a step which I believe is in the right direction and should prove of great benefit to our plant. You all are aware that the steel industry is rapidly becoming a specialized industry and there is no reason why plant maintenance should be figured any different from the trade, in other words, use the proper grade of steel for the job and get away from the practice of using anything that is available. To accomplish this we have enlisted the aid of the Metallurgical Department, they to recommend steel specifications and heat treatment for jobs of a particular nature or where a piece of equipment becomes a maintenace problem. The Metallurgical Department through a follow up system have a complete record of the job enabling them to make an intelligent study of failures and their correction. This is of particular value in the use of shafting where a large field exists for improvement and the cutting of maintenance costs. The use of cold drawn steel for line shafting is the general practice at our plant where stresses are not high and if keyways are cut only at the ends of the shaft. We have found that if keyways are cut at or near the center of a cold drawn shaft, it is very often thrown out of alignment making it unfit for use. This may not be noticed until the shaft has been installed causing further damage to equipment.

(4) We have our share of cranes built twenty or thirty years ago and they are not all confined to one manufacturer. On one particular type of crane, of which we have quite a number, the trolley rides between the girders and were of such design that when it was necessary to change a shaft, the trolley had to be practically torn down due to pyramid bearing, etc. Having a number of old motors of the same type in stock, we had a trolley designed using these motors and installed sufficient, all similar except the span, to eliminate all our problems on this type of crane so far as trolleys are concerned. On the bridge of these cranes there were two separate brackets on each axle made of cast iron, not bushed. We installed cast steel brackets, combining the two brackets into one casting, designed for MCB bearings and standard oil box and our problem died a natural death.

(5) Our maintenance troubles covering old cranes in the plant, have largely been eliminated because of our constant efforts to get rid of all maintenance jobs which proved to be problems. I don't wish to imply that all is easy sailing at our plant, that is impossible, but we have licked most of the real maintenance problems and reduced them to ordinary crane

maintenance, particularly where old and obsolete cranes are involved.

(6) The crane manufacturers are occasionally on the spot with the maintenance department coming to their rescue, for instance—some time ago we had two gantry cranes built by a prominent crane manufacturer serving an open hearth stock yard. The service was constant and very severe. The stock-yard was located opposite a railroad depot where thousands of people waiting for trains would spend their time watching the operations of the gantry cranes. The cranes were old, had seen hard service, were badly worn at bearing seats and the trolleys particularly were very noisy and very expensive to maintain. The crane manufacturer's name plate was mounted on the bridge girders and at certain locations in the yard, could be read from the station platform. We decided that the noise was not a good advertisement for us, and I am sure it was not for the crane manufacturer. The maintenance cost was altogether too high, so we installed two of our previously mentioned trolleys. The results were very gratifying both as to noise and maintenance expense. Shortly after the trolleys had been installed, we received an inquiry from one who had watched the operations of the cranes from the station platform. He wished to know the name of the manufacturer who had built the cranes, mentioning in his inquiry the smoothness of operation.

(7) Bearings are a subject that have received considerable discussion but it might be well to mention a few of our experiences. On our modern cranes, we are using anti-friction bearings throughout except on the track wheels. So far we have had practically no trouble to speak of, and I am sure our maintenance cost has decreased by their use. If it were possible to have ideal runway conditions at all times, anti-friction bearings could be used to advantage on track wheel axles but not having those conditions, it is our belief that M.C.B. bearings will furnish the most satisfactory results with a minimum amount of attention. Anti-friction bearings are ideal on sheave wheels and worm drives and we have had very good results from use in such locations. On a set of sheaves used on an open hearth crane it was necessary to rebush them about every six to nine months. Over six years ago we installed anti-friction bearings in the sheaves which have been in operation ever since with no replacements.

(8) Lubrication used in the proper place is indispensable and used in the wrong place is destructive. Many of the present steel mill products are damaged in the manufacturing process if oil or grease is permitted to drop on them and we must watch the lubrication of our cranes to prevent this. Grease properly applied is one of the best lubricants. It works well in the cellar boxes of M.C.B. bearings for light cranes but I have found its application to the track wheels of heavy open hearth cranes not so successful. Oil works best on these cranes. Drippage of oil from cranes can be remedied by applying felt wick oilers where the wick is kept in contact with the journal by means of springs. I have found the use of such devices quite satisfactory. The proper use of lubricants by the crane operators and repairmen is of the utmost importance. Good training in this respect will go a long way in solving lubrication problems.

(9) In conclusion, I want to mention one important point in the maintenance of cranes. You may have a modern, well designed crane having heat treated gears, pinions and track wheels, alloy steel shafting, anti-friction bearings, hydraulic brakes and every thing else that is a part of an up-to-date mill type crane. Install this crane on a poorly designed runway without proper bracing or ties, or on an old runway that is extremely out of line or out of span, then you have a real maintenance problem. The extra money spent for greater efficiency is lost because no crane will operate efficiently under these handicaps. The condition and maintenance of cranes is dependent on the condition and maintenance of runways to a great extent regardless of the type or design of the cranes. We have found that taper tread wheels will correct runway troubles within reasonable limits but it is not a cure all and should not be considered as such.

GENERAL MAINTENANCE

By T. B McELRAY
Supt. of Light and Power, Carnegie Steel Company, Youngstown, Ohio

In the discussion of the subject allotted for today, I wish to note first some improvements in design which have resulted in lower maintenance costs. For, as we all know, no real progress in such reduction in costs can be made unless the factors which contribute to these excessive maintenance expenditures have been corrected or eliminated.

Welded crane bridges have not as yet come into general favor. This is due primarily, I believe, to the fact that the welding art has not progressed generally to the degree required by steel men in this class of structure. However, my opinion is that eventually this method of fabrication will have become advanced to such a degree that crane users will have no hesitation in specifying same. This belief is borne out by the fact that welded end trucks and trolleys are coming into almost universal use. The advance already made in welding has rendered almost obsolete such steel castings and a further improvement in the art will without doubt bring the welded girder into universal use.

Numerous changes of minor importance are coming into more general use, such as hardened sheaves, equalizer sheaves in pivoted bearings, allowing hoist cables to swing with the trolley motion without impinging on sheave flanges, tapered hardened bridge track wheels, single reduction worm drives for hoist and trolley, hydraulic bridge brakes, two bridge motors per crane, controllers and resistance on footwalks or in an additional cab and two brakes on hoist gearing.

Roller bearings are becoming more generally used and instances where users have changed back to bronze bearings are due largely to designs not providing for forces except those caused by the weight of the parts which the bearings sustain. A lack of provision for ample size to compensate for these additional stresses has, without exception, resulted in bearing failure with its adverse reaction toward roller bearings. This same lack of generous design

in worm gearing has caused a like reaction toward this form of drive on the trolley motion.

I believe the use of plain motors on bridges of cranes will come into more general use, due to the lesser torque strains on the bridge girders, the elimination of the outrigger girder with a resultant closer approach of hooks to end of buildings, and the placing of all gearing strains on the end trucks where such strains belong. Such construction makes also for a cheaper motor and eliminates the possibility of oil leakage at the center of the crane where such leakage causes much concern where finished material is being handled. I believe that the changes embodied in these items which have been enumerated, will result very materially in an appreciable reduction in operating costs.

Also on all existing cranes, I believe we would be making a good investment if we would eliminate all drum type controls and supplant with automatic, not only from the maintenance angle of the drum control but the automatic control assures a better control of the crane and eliminates maintenance from the abuse which most operators seem to delight in giving cranes.

Redesigning all sheaves and blocks to accommodate anti-friction bearings, I believe, is a very good place to reduce maintenance costs. Using approved wipers on all bridge and trolley track wheels not only eliminates waste of oil but also, I believe, gives longer life to bearings and shafting and also helps to remove the ever increasing complaint of oil dropping on finished products.

I suppose it is unnecessary to suggest eliminating cast gears and replacing with hardened rolled sections where practical and using tool steel pinions, but I believe a savings could be made by "nitriding" or chromium plating all bearing surfaces, especially on sheave or track wheel shafting.

I believe that all the above mentioned suggestions would materially reduce the maintenance costs on old cranes now in service in steel mills.

GENERAL MAINTENANCE

By A. W. DUNCAN
Electrical Supt., Weirton Steel Company, Weirton, W. Va.

During the past 20 years we have attended a number of meetings of this organization and listened to many of the most enlightening papers and subsequent discussions pertaining to electrical overhead traveling cranes, and I would like to take this opportunity to extend my personal appreciation and congratulate those of this organization who have heretofore so ably and successfully presented their views on this subject. The good judgment and unrelenting efforts on the part of these individuals is alone responsible for having brought the development of this class of equipment up to its present day high standard of quality and efficiency.

It is true that today manufacturers of heavy materials, especially iron and steel products, depend on overhead electric traveling cranes for the successful and economical handling of materials and supplies, together with the erection of and repairs to processing machinery and lastly the loading of the finished product for shipment to the customer. It is therefore obvious that if our manufacturing operations are to become highly efficient, processing schedules must be maintained and repairs and replacements of machinery must be quickly completed and most important, the order shipped at the time specified by the customer. If this condition is to be realized the overhead traveling cranes must be ready to give safe and prompt service at all times.

I have been requested to discuss this paper on the subjects of bearings, lubrication, gears, pinions and shafting.

With the kind indulgence of our chairman and those of the organization who are present, I would like to talk in a more general way on the maintenance of Electric Cranes.

At various times during the past 20 years this organization has drafted and redrafted specifications for Electric Cranes which covers, very much in detail, the entire equipment. Some of these have even gone so far as to include formulae for the raw materials used in the manufacturing of bearings, track wheels, shafting, gears and pinions.

These specifications referred to have been fairly well followed by purchasers of equipment. However, certain details have been changed from time to time to suit the particular fancy or needs of the individual making the purchase.

If our maintenance problems happen to be bearings, we have manufacturers of babbit metal, bearing bronze and anti-friction bearings of both the roller and ball types. The manufacturers of these materials are experts in their line and once our problems have been presented to them in the right manner, they are able to furnish us with materials that will give us the required results. This condition is also true from the standpoint of gears and pinions, whether they be of the spur or herringbone type. Our lubrication problems, we are able to solve to our satisfaction with the assistance of the expert in this line, in as far as the quality of oils and grease are concerned. There are also manufacturers of steel for shafting that are able, with our help and knowledge of requirements, to supply satisfactory materials. By this I am merely attempting to emphasize a fact of which we are all aware that we are living and doing business in an age of specialists in practically all lines, and that it does not matter so much what parts of any equipment might fail, we are always able to replace it by products or grades of material which will give satisfactory service.

The ability to work these problems is a matter that is largely up to the engineer in charge of operations and his organization. Therefore, it is my personal opinion that our real problem is the selection and training of men in our organizations to properly maintain equipment of this nature.

In our larger industrial operations, it is the general practice, I believe, for the electrical department organization to handle both mechanical and electrical maintenance on overhead traveling cranes. This is as it should be, in order to completely eliminate division of responsibility between two or more departments. This works out particularly well for the individual or individuals doing this class of work, if properly trained are not only able to repair an electrical failure, but quickly locate the cause, which in

the majority of cases is due to some mechanical defect, apart from motor or control.

I do not believe there is a class of work done in any industry which requires more caution in the selection of and more thorough training of the individual than that for electrical crane repair work. My experience has been that even though we select men having more or less natural mechanical ability for these jobs, that it requires a long period of intensive training and instruction to develop them into first class workmen in this line.

The overhead crane is an important piece of machinery located at various heights from the main operating floor and is therefore more or less isolated, together with the fact that there are usually a great number of production superintendents or foremen whose work is served by this equipment, that are justly ready to critcize delays of even the shortest possible duration, and if we are to get the results we have a right to expect, the man or men called upon to make repairs after a failure has occurred, must be physically active, quick thinkers and expert mechanics, and should be of the type that will readily grasp the importance of doing his work well. After the selection of these men have been made the training period begins and the individual must first be sold on the idea that, he has been placed in charge of the perfomance of a high piece of electrically operated mechanical equipment, and that he is responsible for its giving satisfactory service to the department or departments which it serves, and in as much as the work that he is required to do is probably the most hazardous, from the standpoint of personal injury to himself and others, to be found in the steel industry. He must be made to realize the importance of becoming a safe worker. The next step is to sell him the idea of preventing failures by the regular periodical inspection method and he must be made to realize that a loose bearing cap, if not quickly located and corrected will eventually cause excessive wear to bearings, shafting, gears and pinions, and that these defects will also eventually cause electrical failures by damage to both motor and control equipment. He must also know that a bad runway or one which has bent, worn or loose rails will cause excessive wear and early replacements of track wheels and their journals and bearings, if this defect is not reported and quickly corrected. He must be taught the importance of lubrication and must know a grade of grease or oil which gives satisfactory results on one application will not always do on another, where conditions are entirely different.

He must be made to know that control apparatus as applied to crane motors is a highly engineered and efficient piece of equipment and that bad contacts or the cutting out of loose or broken resistor grids, will eventually result in damage to the motors, thereby causing its early replacement.

By a full realization of these and many other facts, delays and maintenance costs will be reduced to the lowest possible minimum.

Much has been brought out in this paper and discussion pertaining to the maintenance of overhead traveling cranes, however, I am a firm believer that our real maintenance problems can be solved to a great extent by specifications prior to the original purchase and proper training of our maintenance organization, than in any other way.

GENERAL DISCUSSION

Discussion Presented by

H. W. Ball, Asst. Chief Engineer, Morgan Engineering Company, Alliance, Ohio.
Leroy Brooks, President, The Tool Steel Gear & Pinion Company, Cincinnati, Ohio.
B. R. Shover, Consulting Engineer, Pittsburgh, Pa.
J. L. Young, Asst. Gen. Mgr., Industrial Division, Timken Roller Bearing Company, Canton, Ohio.
W. E. Miller, Supt. of Maintenance, Bethlehem Steel Company, Johnstown, Pa.
G. R. Carroll, Electrical Superintendent, Jones & Laughlin Steel Corp., Aliquippa, Pa.
A. W. McAuly, Electrical Supt., Edgewater Steel Company, Oakmont, Pa.
R. J. Harry, General Manager, Alliance Machine Company, Alliance, Ohio.
J. Farrington, Electrical Supt., Wheeling Steel Corp., Steubenville, Ohio.
M. J. Conway, Fuel Engineer, Lukens Steel Company, Coatesville, Pa.
W. A. Marshall, Master Mechanic, American Sheet & Tin Plate Company, Farrell, Pa.

H. W. Ball: I did not come prepared to be called on. We have worked with various steel plants to try to improve cranes and appreciate what has been done with new ideas along the line of strippers, soaking pit and charging machine cranes.

Among the more recent developments in which we have taken a part I would like to mention some transfer cars and pushers which we have designed for the insertion and removal of large annealing boxes in the annealing furnaces. We have developed a method of operating from the cab or platform the dogs which push or pull the furnace trucks carrying annealing boxes in or out of the furnaces. This type of machine has a normal pushing capacity of 100,000 pounds with a maxium emergency capacity of 200,000 pounds. This is ample for moving fifteen or more trucks with a total weight of around 1,300 tons.

We have designed another type of transfer car which raises and lowers the annealing boxes which weigh around 60 tons each, and deposits them in the furnace or on the storage platform without the use of furnace trucks.

One of the new features in crane design which I think deserving of mention is our new foot brake which is adapted for either hydraulic or mechanical operation. This brake is built for the longest possible life under severe service conditions. Not only are hardened pins used at all wearing points—but hardened bushings (actually outer races of small roller bearings) are used. The brake shoes are located above and below the brake wheel instead of at the sides as has been the usual practice. This has the effect of providing a cover to keep the wearing surface of the wheel free from dust and grit, which we believe is a very important feature. The linings of these brakes are ground to fit the curvature of the wheel thus avoiding the danger of wearing thin in certain spots.

There are some cases where it is very desirable to provide an additional safety feature in connection with the foot brakes of heavy cranes. For this purpose we have combined with our hydraulic foot brake

an electrically operated feature arranged to set the brake instantly and automatically in case of power failure or in case of failure of the hydraulic operation.

I believe the papers given here have covered the field very nicely, and appreciate very much having had the opportunity of saying these few words.

Leroy Brooks: I appreciate very much the opportunity I have had to listen to the presentation of this subject, but do not believe I can contribute anything of special importance to it. We are not crane manufacturers, nor do we come into direct contact with the many operating problems which you men have to handle. But we do manufacture hardened gearing, track wheels, brake wheels and other parts for cranes and it is our purpose and desire to co-operate with you operating men in supplying you with the highest quality of such crane parts suitable for your particular requirements.

There is one thought I might mention in connection with the matter of old cranes, which has already been referred to by one of the previous speakers. Whenever you greatly increase the loads and speed of such cranes in excess of those for which they were originally designed, you should not blame those of us who supply such parts as gears and track wheels for the possible failure of such parts which may thus be overloaded far beyond their normal capacity.

B. R. Shover: To those who can go back twenty-five years or more in this business, I cay say confidently that we feel very proud of the advance that has been made in the electric traveling crane. The large majority of the improvements are directly due to the efforts of this Association, but we should not puff out chests too much because one of the surprising things to me is that many of the troubles that are mentioned here are the same as those experienced forty years ago. We used to buy cranes according to the purchasing agent's idea of so much per pound, and the crane builder who gave the lowest price per pound received the order, so that it is gratifying to see that more attention is being paid to brains and design than to pig iron.

Some time ago Julian Kennedy made the remark that if the model "T" Ford was designed along the lines of the electric traveling crane, 1?" armor plate would be required for street paving, and there is some truth in that statement. I remember seeing two 150 ton ladle cranes, designed for the same speed, but the hoist on one crane had two 80 H.P. motors while the other was driven by four 100 H.P. motors and their weights were in about that proportion.

While in India I had an excellent example of what the weight of a crane meant. The original open hearth installation was equipped with two 100 ladle cranes of German make which cranes had been in operation over two years during which time they were run and repaired entirely by Indian labor, and had given excellent satisfaction. An extension to the open hearth required a third crane and because of the World War, we were obliged to secure this crane from America and found that the steel in the column and girders had to be almost doubled in order to carry this American crane. This experience would indicate that we have not given sufficent attention to design and quality of material used in our cranes.

A Member: What is the objection to shunt wound brake coils on standard cranes?

B. R. Shover: In the early days, all brake coils were shunt wound, and much trouble on motors and brake bands resulted from the slow action of these coils, probably due to a combination of reactance and poor voltage.

A. W. McAuly: The purpose of a brake on the shaft of a hoist motor is to prevent the rotation of that shaft at all times except when current flows through the motor. Conversely, when voltage is applied to the terminals of the motor, the brake should open instantly and it should close the very instant that current ceases to flow in the motor. The series wound brake will do this whereas the shunt type has a certain amount of inductance which makes the action somewhat sluggish. Furthermore, it often happens that the "kick-back" voltage from the shunt coil ruptures the insulation and causes trouble. Another disadvantage is its increased cost.

J. L. Young: I recently heard a paper delivered at Canton, Ohio, on an interesting subject. In this paper the speaker was describing the metallurgical aspects of the various parts of a radial type airplane engine. In the design of the crankshaft they have found it necessary to use a splint crank pin for the assembly and removal of the connecting rod bearing mounting. In airplane engines it is necessary after a certain specified number of hours to completely tear down the engine for inspection of all parts and it is necessary to remove this connecting rod assembly from the crank pin which means that the crankshaft must be taken apart for this inspection.

Their experience has shown that during this removal and reassembly they have constantly scored the parts of the crank pin and an effort was made to eliminate this condition with the result that someone in their shop thought of an idea of tin plating the male portion of this assembly with the result that they have obtained a unit that can be assembled and reassembled a number of times without scoring the crank pin parts.

This tin plating is merely a flash plating job in order to fill the pores of the steel to allow more or less a slippery surface for this work. They have found this application so successful that they are now applying it to other pressed assembly members of the engine and the thought in bringing this to your attention is that possibly this same idea might work into a number of positions in overhead traveling cranes for the mounting and removal of wheels, bearings and gears.

This flash tin plating does not increase the diameter of the shaft and therefore there is no necessity of allowing extra fitting tolerances to take care of this condition.

The Timken Roller Bearing Company has been carrying on an investigation for a number of months of the relief of stress in axles and wheel parts. In this study we have found the concentration of stresses of great interest in comparing a straight shaft versus a shaft with a turned shoulder and the effect of the shinking of gears and wheels as well as bearings on shafts by various methods to relieve the strains set up in the shaft under the various conditions.

These studies indicate that the elimination of a shoulder on the shaft will allow the use of a smaller diameter shaft and furthermore the relief of stress concentration at the end of the gears, bearings or

wheels even on the straight shaft will also tend to relieve the stress concentration at those points.

At the present time this is in the experimental stage but we hope to have sufficient information in the near future to present this story to you in more concrete form.

W. E. Miller: In Mr. Carroll's paper this afternoon there was one thing not exactly clear to me. I understood Mr. Carroll to say that he suggests placing the rails in the groove of tie plates and welding the tie plates to the runway. To my mind, this would not prevent a heavy end thrust upsetting the rail. Our practice is to weld the standard railroad rail brace used on the curves, to the crane runway, to hold the rail in position and still allow it freedom to move longitudinally from expansion due to temperature changes.

In connection with another subject, Mr. Shover remarked about the weight of cranes used in Germany. He said the German cranes were considerably lighter than our cranes. I have never been in Germany, or India either, but it was my understanding that the German cranes operated at about the same speed as our cranes did about twenty-five years ago. Due to the construction of cranes of those days, we had considerable trouble with the line shafts. They would not stay put, but shimmied across the bridge.

I would like to hear from Mr. Shover as to the speed of these cranes, and from Mr. Carroll on the tie plates.

B. R. Shover: The comparison previously noted between the German and the American cranes, according to the best of my recollection, the speeds were practically the same.

G. R. Carroll: If I understand Mr. Miller's question right, he is concerned about the rail turning over. We have never had that trouble. There is no reason why such devices as he mentioned can not be used if necessary as long as they do not restrain the rail from moving lengthwise. In this connection we have found that where tapered tread track wheels can be properly installed, the side thrust problem disappears.

W. E. Miller: The brace I mentioned is an adoption of the standard pressed rail brace which is spiked to the ties to brace the rails at corners in standard railroad practice. It seems to me that the tie plate construction would be alright, provided body bound bolts were used at the joints. The rails should be cut square at the ends and the fish plate holes should be drilled a little bit smaller than the bolts. The rails when installed, should be butted tight together and the bolt holes in the fish plates and rails reamed to insure a tight fit for the bolt. The rails then cannot spread apart at the joints. With the ordinary fish plates the rails can pull apart a little at the joint and pounding starts. The more the rails pull apart the worse the pounding becomes. I feel it makes good construction to install the rails with body bound bolts in the joints and with the rail braces. If tie plates were used, they should be installed pretty close together and should be placed under the joints to strengthen the joint.

I might add that some people have the idea that tapered tread track wheels are a cure-all. Considerable end clearance is absolutely necessary for tapered tread wheels when they are used. On many old installations this clearance is not available and the tapered tread wheels are not a success. In other instances with sufficient clearance, tapered treads on all wheels will not work, but a combination of tapered tread wheels on one side and straight tread wheels on the others will work perfectly.

A. W. McAuly: What is the modern practice when using a worm gear drive on the hoist; do you have a dynamic lowering controller on such a machine; or do you depend on the action of the worm gears to hold the load in the lowering direction and therefore increase the lowering speed with light loads.

R. J. Harry: In some older makes of cranes the inefficiency of worm gears was utilized for the braking effect produced in lowering heavy loads. The modern worm gear installation is a vastly different piece of mechanism from the one of twenty-five to thirty years ago.

During the past few years there has been a marked advance in worm gear design, and worm gear manufacturers are now guaranteeing efficiencies of 95%. As a consequence it is necessary to employ dynamic braking to control the lowering speed of worm driven crane hoists, just the same as with spur drive. With some old type self-locking worms it was necessary to use power to lower a load, but that condition does not obtain with the present highly efficient worm drive.

J. Farrington: In 1901 the Youngstown Engineering Company used the worm as a mechanical brake on their cranes and applied it to the outside of the drum, the idea being, if the hoist gearing should break the worm would lock and hold the load from falling; but the customers who bought the cranes did not think very much of the scheme.

W. E. Miller: I would like to add to Mr. Harry's remark about the worms of 95 to 98% efficiency. When we bought our first worm driven crane, I insisted on a size larger worm than was recommended by the manufacturers, in spite of the fact that they said the crane would look out of proportion, and that it would cost us $300.00 more. I believe that was the cheapest insurance we ever bought, because the crane has been running for years without any trouble, the only maintenance on the worm being to clean it out occasionally and put in new oil. We may have sacrificed the efficiency of the worm somewhat, but it has paid in the long run.

M. J. Conway: Mr. Harry, in his paper mentioned the use of alloy steel as applied to crane girders, and especially referred to silicon steel being used in built up frame girders.

I am interested to know the exact analysis of this plate steel, and especially the silicon content, if Mr. Harry will supply me with the information?

R. J. Harry: The steel referred to is Sil-Ten which conforms to structural silicon steel A. S. T. M. Specification A-94. From 1915 to the present time there have been large tonnages of this steel used in the important bridges built in this country. This material is furnished to the following chemistry:

Carbon	.40	Maximum
Phosphorous	.04	"
Sulphur	.05	"
Silicon	.20	Minimum

W. A. Marshall: I am connected with a tin plate interest, and would like the crane manufacturers to give consideration to grease dripping, particularly on gears, which has always been a source of trouble.

The anti-friction bearing is quite easily sealed but rather expensively. To my knowledge there has been no seal design for sleeve type bearing and it is something which is needed today.

BRIDGES AND TROLLEYS

By B. A. E. ROSENQUIST, Design, Engineer, Carnegie Steel Co., Duquesne, Pa.

I am going to limit my discussion to mentioning a few improvements to the bridge structure and trolley frames which we have made and which may be of general interest.

Improvements to Bridge Girders

Girders with worn and corroded top plates have been repaired by the installation of a new plate on top of the old one. The new plate to be wide enough to clear the rivet heads, and welded to the old plate with a continuous weld, in order to exclude water and dirt. We have also been able to stiffen many girders by welding flat steel vertical stiffeners to the web plates and also to the top and bottom angles on both sides of the box girder.

In the case of twisted box girders, no successful means of repair has been found. We have been able to take a certain amount of twist out of a girder by shoring up the center to relieve it of the strains due to its own weight and forcing it back to its original position. We then weld stiffeners to the web plates and top and bottom angles. The best solution of course is the replacement of the twisted girder with a new one, with the addition of a lattice outrigger girder to help carry the load. This permits the installation of a wide footwalk for the mounting of magnetic controllers and resistance banks.

The conventional way of mounting rails is by laying them directly on the top plate of the girder and bolting the rail clips to the girder to hold the rail in place. On outside cranes, this method results in rapid wear of the top plate, requiring replacement within a few years. This excessive wear is due to the sand and water which collects between the base of the rail and the top plate, which forms an ideal grinding compound for the movement of the rail on this plate.

We have recently tried a new method for mounting the trolley rail on the bridge girders. Flat steel strips, $\frac{3}{8}$" thick, 8" wide, and long enough to clear the rivet heads on top of the girder are welded to the top plate, on which the rails are mounted and lined up. The rails are held in place by standard rail clips welded to the above mentioned plates. To prevent the rail from moving back and forth along the girder, a plate is welded to the top plate at both ends of the girder.

Misalignment of Bridge Structure

The misalignment caused by girders working loose from the end carriages has been remedied by electric welding. This means of taking care of this difficulty has been entirely successful. We have to date not found a single bridge structure working loose after once being welded.

In cases where the crane was equipped with cast iron end trucks, we replaced them with welded structural end trucks and welded the girders to same.

Trolleys

The maintenance costs for the early type trolley with cast iron side frames and built-in mechanical brakes have been very high. For this reason and for the sake of safety we have rebuilt many trolleys of this type. The cast iron side frames have been replaced with cast steel side frames, welded to structural cross members and end channels to form a very rigid trolley frame.

In many cases the equalizer sheave and support has been moved up from under the trolley to the top of the trolley where it is accessible for inspection and replacement of worn cables and parts. The equalizer sheave has been equipped with a roller bearing and a close-fitting removable rope guard, preventing the rope from jumping out of the equalizer sheave.

By installing the more reliable shoe brakes and dynamic lowering controllers, we have been able to eliminate the mechanical brakes and the solenoid operated bandbrakes. Both of these brakes have been a source of trouble and high maintenance in the past.

Painting

One excellent way to maintain the bridge structure and trolley is to give them two coats of paint every three years, the second coat usually being aluminum paint. As a rule the cranes are not painted frequently enough to prevent rusting. The cost of painting a crane which has been permitted to rust is excessive, because all rust must be removed in order to make a good paint job.

In conclusion will state that with the gradual replacement of the old type cranes with modern cranes equipped with anti-friction bearings, worm drives, heat treated tapered track wheels, etc., we will finally secure low maintenance costs, the goal we have been long striving for.

MAINTENANCE PROBLEMS ON OLD CRANES

By G. W. BAUMGARTEN
Asst. Electrical Engineer, Carnegie Steel Co., Duquesne, Pa.

Brakes, Motors, Control and Wiring

Brakes, motors, control and wiring on overhead electric traveling cranes can be compared to the heart, brain and nerves of the human being, and are therefore of vital importance to the proper functioning of an electric crane. Adequate brakes are essential on cranes but the solenoid brakes on the older cranes are not adequate today and as opportunity permits we are applying magnet operated brakes.

We have used special brake wheels as well as standard cast steel wheels and on some of the special wheels we had some breakage which might be traced to uneven heating. A standard cast wheel equipped with cast re-inforcing fins which by their fanning action helps to keep the wheel cooler, eliminated our trouble. Wheels as they become worn are welded on an automatic welding lathe at a lower cost than new wheels. The pins as they wear on an old brake are replaced with hardened pins and as holes are worn, the brake mechanism is welded up and re-drilled. Brake lining of the woven, moulded and semi-flexible type is used. Brake coils on modern brakes cause very little trouble, but on the older type solenoid brakes where they are exposed to the weather, they roast out short and ground themselves. This maintenance problem is of course eliminated when a modern brake is installed.

Motors

Motors that have failed in service are brought to the armature shop and tested to locate the trouble or verify the trouble as reported. We use a test of 1000 volts to ground to check the insulation of the field and armature coils. If armature coils are needed we believe the manufacturer of the motor is best able to supply proper coils, therefore we generally use manufacturer's coils, but we have found where some change is desired in the method of insulating a coil, it is easier to get an independent manufacturer to make it the way we desire rather than to attempt to change the original manufacturer's methods. Wire wound field coils are wound in our own shops.

Shafts

When our welding lathe was first put into service, we decided to weld up worn motor shafts but after several failures abandoned this procedure and are now replacing worn shafts with chrome nickel steel shafting.

All new motors are purchased with anti-friction bearings. On the older pre-mill type motors we had a large number of good motors and a program was initiated of replacing the sleeve bearings with anti-friction bearings. That program is practically completed with the exception of one motor frame size. If the bearing capsule in an old motor is loose and begins to vibrate the capsule seat is worn so that we find it necessary to weld up and re-bore the case in order to get a good fit for the capsule. The greasing of the anti-friction bearing motors is in some cases taken care of by men from the shop and in other cases the motor inspector does the greasing and keeps a record. Formerly when a motor was received in our shop and the necessary repairs made, it was connected up and run for a few minutes before being checked as satisfactory. Frequently after an hour's service on the job these motors again showed signs of distress so we have built a testing bench and each motor after it is repaired is given a full **load** test for 1½ to 2 hours which indicates that the bearings are properly adjusted and that the motor is ready to be used again.

Control and Wiring

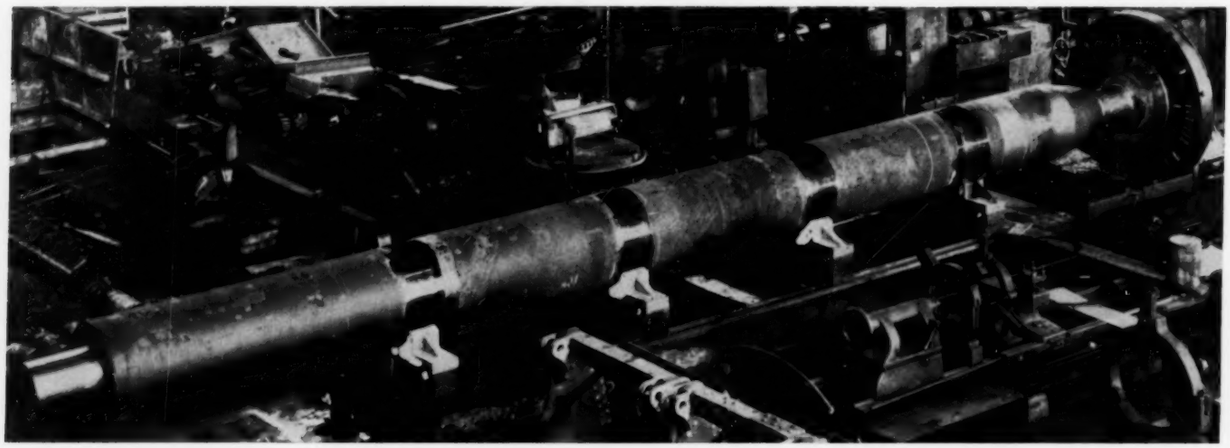
Some years ago our stock cranes were equipped with the old style reversing dinkey controllers on the hoist and when a 43" magnet was lowered to the ground and plugged, the arcing at the commutator was very bad. Therefore we decided we would have to limit the lowering speed, especially after a test indicated that we were exceeding the maximum safe speed of the armature. An armature shunt and the necessary grid resistor were added to the dinkey controller in the lowering direction and the wear on both brushes and commutator was greatly reduced. On cranes which are equipped with small cabs we have made an effort to replace dinkey resistance with external grid resistance which contains grids of the proper ohmic value and ampere capacity. Mounting the grid resistors outside the crane cab enables us to mount two dinkey faces on one dinkey frame thereby conserving cab space.

On the old type magnetic crane control which was ten or fifteen years old we replaced the old stationary contact of the accelerating contactors with a modern type equipped with blow-out coil and arc chute. This change reduced the tip wear on these controllers. When re-wiring old cranes we add protective panels which include a main line safety switch, rear of board mounted or a protected knife switch and double line contactors. Overload and no-voltage protection is provided for all motors.

All wiring is pulled into conduit which is spot welded to the crane structure. Six, eight and twelve conductor coded control cable is used rather than a similar number of individual strands of #12 rubber covered wire. All wiring diagrams are traced on tracing cloth for a permanent record and to insure a prompt economical supply of correct blue prints. This diagram includes a main and control schematic —a sequence table and a cross reference to the resistor sketch. All control resistors are labeled on the diagram by catalogue number and ohmic value.

A card index is in the maintenance engineer's office and gives the correct motor and control data for each installation, while a second index is subdivided according to the control manufacturer and facilitates the rapid location of the proper wiring diagram.

A bound booklet covering each installation is given the section foreman and contains control wiring diagrams, resistor sketches and control spare part data. This enables the foreman to order promptly and accurately from the storeroom, the necessary control parts which he may need.



In this illustration is shown a huge bending roll, 42 feet long, 36 inches diameter and weighing 80 tons which had a fracture near one end repaired with thermit.

Thermit Welding

By J. B. TINNON
Manager of Sales, Metal & Thermit Corp., New York, N. Y.

Paper presented at the A. I. & S. E. E. Annual Convention held in Cleveland, Ohio, September 18, 19 and 20, 1934.

While many of the members of your society are undoubtedly familiar with the basic principles of thermit welding, it may be advisable to review these fundamentals briefly for the benefit of those who are not so well acquainted with the process.

Thermit welding is distinguished from other processes primarily by the fact that it is the one welding method which requires no external source of energy or heat. The process is based on a chemical phenomenon, namely, the fact that aluminum has a much greater affinity for oxygen than any other element. Very early inventors recognized this fact and employed it as the basis of a method of reducing or deoxidizing metallic ores and oxides; particularly in the manufacture of rare metals. Here the substitution of aluminum for carbon as the reducing agent resulted in a more active reaction which required no external heat. It remained, however, for a German scientist, Professor Dr. Hans Goldschmidt, to discover (about 35 years ago) that, if a mixture of metallic oxide and finely divided aluminum were placed in a crucible and ignited in one spot, the reaction of this spot would furnish sufficient heat to propagate the reaction throughout the entire crucible until the contents were converted into a molten mass of metal and aluminum oxide slag. He also discovered that this reaction would proceed at a rate which would make possible the production of any quantity of metal, up to a ton or more, in a single reaction lasting only about thirty seconds. The inventor was not long in applying this discovery to the welding of ferrous metals, and, while there have been numerous improvements and refinements in procedure and in the design of materials and equipment, the method used today is essentially the same as that evolved more than three decades ago.

The thermit welding process depends principally on the alumino-thermic reduction of iron oxide. The oxide used is generally Fe_3O_4 in flake form. The physical size of these oxide flakes, and the percentage of fines included in the mixture, have considerable effect on the time of reaction and the resultant heat, which is generally about double the temperature of ordinary molten steel. Reaction time may be further controlled by the addition of metallic elements to the thermit mixture. It will readily be seen, therefore, that in designing thermit mixtures for use in welding, there are sufficient variables to permit not only close control of the speed and temperature of the reaction but also the physical properties of the weld metal.

In a general way, this welding process is exceedingly simple. It requires no extensive training, no particular manual dexterity on the part of the operator. In making a weld, it is necessary only to follow a few simple instructions. For example, the parts to be welded are first lined up with a small space left between the ends, or the ends may be butted tightly together and the fracture cut out to form a straight sided gap. A special wax is then placed between and around the ends of the parts to form a semi-circular collar the exact size and shape of the desired collar of weld metal. A sheet iron mold box is placed around the part and molding material is rammed in around the wax pattern. Pouring gates, heating gates, connecting gates and risers are provided. The parts to be welded are preheated to a good red heat, the flame of the preheater burning away the wax pattern and drying out the mold. When the sections have reached the proper temperature, the heating gates are plugged and the thermit, in a conical shaped crucible, is placed above the pouring gate.

The thermit reaction is started by means of a small quantity of ignition powder. In from 20 to 30 seconds, when the reaction is completed, the thermit steel is tapped from the crucible into the mold. The mold is allowed to remain in place long enough to

assure proper annealing of the weld. The risers are then cut away and the weld may be finished or machined as desired.

The inherent advantages of this welding process as an emergency repair method, particularly where very heavy sections are involved, have led to its being almost universally adopted throughout the iron and steel industry. An interesting sidelight, illustrating the extent to which it is being used, is the questionnaire sent to every important steel mill in the country by the official publication of your society late in 1933. Almost 80 per cent of those who replied said they used it for heavy repairs, and those who replied reported 100 per cent excellent results.

This widespread acceptance of this type of welding throughout the industry is due primarily to three outstanding factors. First of these is the low cost of thermit repairs in contrast with the cost of new parts for replacement. Second is the speed with which thermit repairs can be made as compared with the length of time required to obtain and install new parts. Third is the dependability of the welds made and the fact that repairs are permanent repairs which frequently result in parts being made stronger than when new. The first two of these factors are of genuine economic importance in steel mill operation. They provide the superintendent and master mechanic with a low cost method of meeting emergencies. They prevent long and costly shut-downs of whole departments and reduced production of entire mills due to breakdowns of essential equipment.

The cost of making a thermit repair usually ranges between 20 per cent and 50 per cent of the cost of making and installing a new part. The materials and equipment employed are invariably much less expensive than a new casting or forging, and, the larger and more intricate the broken part, the greater this difference becomes. Labor costs, too, are generally lower and still further savings may be effected where a regular thermit welding department can be established and more speed and economy obtained through greater efficiency. The figures in Chart 1, furnished to us by various steel mills, indicate the cost of making typical thermit repairs together with the savings effected over replacing with new parts.

Where time is the essence, however, these figures become almost insignificant. For, when a mill is operating at anywhere near normal output and the breakdown of some important piece of equipment seriously affects production, each day's delay in getting that equipment back in service may mean a loss of thousands of dollars. By shortening this period

CHART 1

WELDING NEW ENDS ON THREE SPINDLES

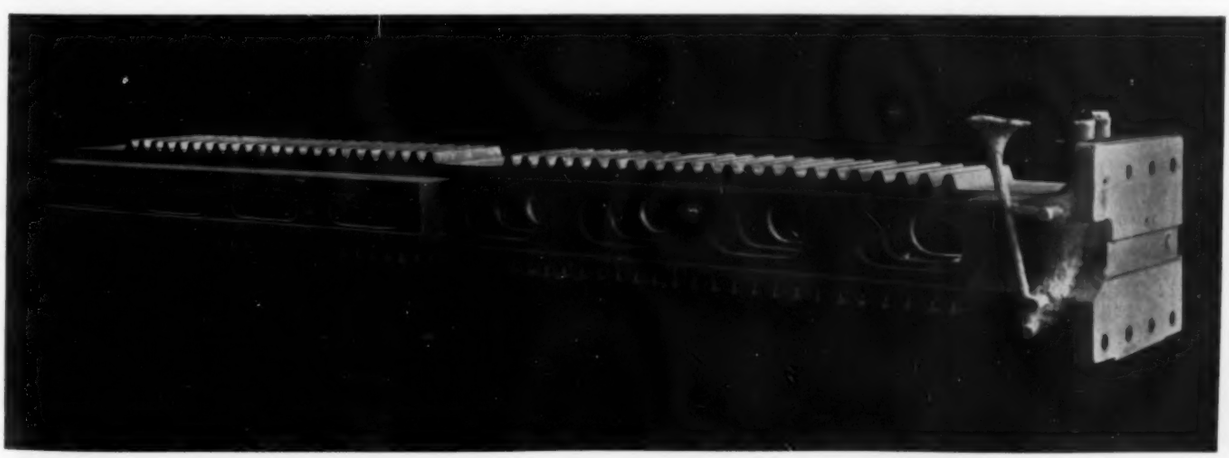
Value of three new spindles		$5,842.26
Thermit	$395.55	
Wax	20.80	
Moulding Materials	42.00	
Kerosene	6.00	
Plugging Material and Thimbles	.90	
Overhead	27.72	
Labor at 60 cents	92.00	
Machine Shop Charges	90.00	
Cost of new ends less scrap value of old ends	507.00	
Total cost of three repairs		1,181.97
Saving		$4,660.29

WELDING MAIN DRIVING PINION—56-INCH BLOOMING MILL

Value of new pinion		$5,375.00
Cost of new end casting	$572.99	
Welding Materials	605.59	
Welding Labor	62.93	
Haulage	5.05	
Machining after welding	366.22	
Overhead (not ascertained)		
Total cost of repair		1,612.78
Saving		3,762.22

WELDING BROKEN SIDE FRAME OF 45-TON LADLE

Value of new frame		$500.00
Labor	$44.75	
Overhead	14.92	
Welding Materials (similar to above)	130.08	
Total cost of two welds		188.75
Saving		311.25



This 12 ton rack from a large ball press was repaired in three days by thermit welding.

of curtailed production from a matter of weeks to one of a few days, thermit welding frequently results in tremendous savings. The repair of a broken manipulator rack by the thermit welding crew of one mill serves as an excellent example. The rack in question had been in service for about a year. No spare was kept on hand. Operation of the mill without the rack reduced production about 30 per cent, and two weeks would have been required in which to obtain a new rack for replacement. The broken part, however, was permanently repaired and reinstalled, ready for service, within two days and the welding department, in this case, was credited with 30 per cent production for a period of ten days.

The dependability of the welds and the permanence of repairs made by this process hinge largely upon the quality of the thermit steel itself and a brief review of the principal items in the welding operation upon which the quality of the weld metal depends is important.

The first questions that usually arise are—how can such a cast steel possibly compare in strength with forged steel, and will not the strength of the welded part be simply that of the cast steel in the weld and not that of the original forging? These are exceedingly apropos questions because if the weld is considered as having only the strength of cast steel, its applications in steel mills becomes very limited. As a matter of fact, it has been proven many times, both in tests and in actual service, that this is not the case. Thermit welded parts, tested to destruction will just as often fail completely outside the weld area as they will in the weld or in the metal adjacent to the weld. Two bend specimens, for example, were taken from welds in 10 in. by 10 in. sections. The bends occur right at the weld and the specimens were bent "flat" without even roughening the outer fibres. The other two specimens are made of thermit steel only.

The strength of thermit steel can be accounted for by theoretical deductions. Steel as cast, differs from forged or worked steel not in its chemical composition but only physically. This physical difference lies largely in the weakness of the grain boundary. Commercial cast steel when solidifying throws out to the grain boundaries a large number of impurities which form part of the cementing medium between the grains and make this weaker then the grains themselves. For this reason, the fractures of cast steel are usually intergranular. Forging, rolling or otherwise working these grains distorts them so that the grain boundary no longer is of importance, the strength of the piece being that of the material itself and not that of the weaker grain boundary. Thermit steels, on the other hand, are produced by the reduction of very pure iron oxide by an almost perfectly pure aluminum, and it is because of this purity that a steel similar to forged steel is produced without refinement by working. Invariably the fractures in thermit steel occur through the grains and not along the grain boundaries so that thermit steel has all the properties of forged steel except its appearance under the microscope. Whether this is the true explanation or not, it is a fact that in every test and by actual service, the physical properties of thermit steel compare favorably in every respect with the physical properties of the highest grade steel forgings.

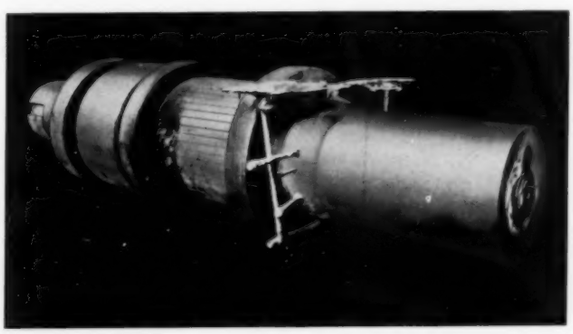
A comparison between thermit steels and forged steels was first brought out prominently during the war when a large company on account of its familiarity with the thermit process, asked the approval of Lloyds' Register of Shipping of the use of thermit welding in the manufacture of stern frames for ships. This approval was readily given in the case of cast steel frames but withheld in the case of forged steel frames. Because years of experience in welding forgings, and particularly the welding of hundreds of heavy crankshafts without failure, had led us to believe that thermit steel could not be judged from the foundryman's experience, the decision resulted in a long series of tests. These tests were very elaborate and consisted in making a large number of welds in 10 in. by 10 in. sections of forged steel approved by Lloyds'. The results are all available but the impact tests are probably the most interesting. Showing a very excellent tensile strength and ductility, they resulted in the approval by Lloyds' of the thermit welding of forged steel frames. Two 10 inch pieces of Lloyds' steel, each about 3 feet long, were thermit welded end to end. After welding the piece was not annealed nor was any work done on it except that the excess metal at the weld was machined off. The resulting specimen, 6 ft. 3 in. long, with the weld at the mid point, was symmetrically supported horizontally on 5 ft. centers and a 3290 pound pear shaped weight was dropped directly on the weld from a height of 18 ft. Progressively in nine drops, the middle of the test piece was deflected downwards 1-7/32 in. without any signs of distress. It was then turned over 180 deg. on the assumption that it could be rather easily broken if bent back again. The drop testing continued until, after six more drops, the piece had practically straightened out. After this, Lloyds' engineer suggested that the weld be sectioned and examined internally rather than to continue the impact testing which might have been prolonged.

Herewith is shown a new pod welded to a pinion.

Since the approval of thermit welding by the various shipping bureaus, hundreds of welds have been made in stern frames of steamers. Although there have been one or two failures, the breaks have never occurred closer than three feet from the weld. While this may not be a true test of the comparative strengths of thermit steel and forged steel, because the excess metal is seldom machined off, it does indicate that the metal next to the weld is not harmed to any extent by recrystallization or otherwise.

Many other tests, both laboratory and practical, could be described, but the foregoing will serve to show that thermit steels are equal to most forged

steels as far as fatigue and impact values are concerned. The other physical properties are easily controlled between certain wide limits in the manufacture of the thermit mixtures. For example, the introduction of various metallic elements into the weld metal in any desired proportions allows for almost unlimited variations in the physical properties of the resultant steel. These elements can be introduced either by means of metallic pieces which are melted in the reaction, or in the form of thermits, namely, combinations of the oxide of the element with aluminum. A long series of experiments with the efficiencies in reaction of the several metallic oxides has determined definitely the combination of thermits required to produce steels of given analysis. Chart 2 gives the formulae showing the aluminum reduction of various oxides and the chemical analysis of the resultant slags and metals. By such means tensile strength, ductility and hardness of the resultant steel also are easily controlled and the tensile strength can be varied from 50,000 lbs. per square inch to 110,000 lbs. per square inch with a corresponding ductility of over 40 per cent in 2 in. down to zero.



This photograph illustrates a new 30 inch end welded to a 50 inch roll.

Having discussed the physical properties and the control of the analysis of thermit steels, the next question is the degree of certainty that the operator has in making every weld a sound weld. The extremely high temperatures so necessary for the welding operation require that the weld be poured at a temperature in excess of 4000 deg. Fahr. Actually the thermit reaction produces a temperature of from 4000 deg. to 5000 deg. Anyone familiar with the casting of ordinary steels and the importance of close control of casting temperature would expect some difficulties to be encountered where this almost 100 per cent superheated steel is employed. Fortunately, however, thermit steels have one great advantage in that they are perfectly deoxidized. The steel man also may be suspicious of these thermit steels because they contain a slight excess of aluminum which, to him, usually means trouble. The difficulties that he has encountered, however, may not be due to aluminum content in the steel but rather to alumina which, because of the lower temperature at which ordinary steels are cast, may remain entrapped. In thermit steels, the metal is as liquid as water. Great quantities of alumina are generated in the reaction and yet none of it appears in the steel itself. In such a highly liquid state, the difference in specific gravity of the metal and the slag (alumina) causes an almost instantaneous and a perfectly complete separation.

CHART 2

FORMULAE SHOWING THE ALUMINUM REDUCTION OF VARIOUS OXIDES

Metallic oxides		Aluminum		Resultant slag		Resultant metal
$3Fe_3O_4$	+	8Al	=	$4Al_2O_3$	+	9Fe
Fe_2O_3	+	2Al	=	Al_2O_3	+	2Fe
$3Mn_3O_4$	+	8Al	=	$4Al_2O_3$	+	9Mn
Cr_2O_3	+	2Al	=	Al_2O_3	+	2Cr
WO_3	+	2Al	=	Al_2O_3	+	W
$3V_2O_5$	+	10Al	=	$5Al_2O_3$	+	6V
$3TiO_2$	+	4Al	=	$2Al_2O_3$	+	3Ti
3NiO	+	2Al	=	Al_2O_3	+	3Ni
MoO_3	+	2Al	=	Al_2O_3	+	Mo
$3SiO_2$	+	4Al	=	$2Al_2O_3$	+	3Si
B_2O_3	+	2Al	=	Al_2O_3	+	2B
$3Co_3O_4$	+	8Al	=	$4Al_2O_3$	+	9Co

Thermit steels, therefore, do not require to be poured at low temperatures to cause them to solidify into dense, sound castings. The presence or absence of defects in the thermit steel depends largely upon the mold itself and upon the material from which it is made. This, for many years, was one of the stumbling blocks of thermit welding and, in an effort to eliminate trouble from this source, all kinds of high grade facings commonly found in steel foundries have been used and most of the well known formulae tried out. The real difficulty was traced to the fact that the fusing point of all clays is far below the temperature of the thermit steel and that the fusing of the clay content in the mold was accompanied by the generation of gas. The problem was finally solved by the selection of the best silica sands and clays and the making of a synthetic molding material which contains a minimum of clay. The mixture is thoroughly mulled in a foundry pan so that, theoretically, at least, each grain of sand is covered with the thinnest possible layer of plastic clay. Molding material of this kind generates much less gas when the thermit steel comes in contact with it and, at the same time, remains porous so that the small amount of gas which is generated passes out through the walls of the mold and not through the steel itself. When ordinary care is used, there is no excuse for defective thermit welds due to molding materials.

Still another factor tending to promote density and soundness in thermit welds is the fact that thermit steels solidify from the inside toward the outside. The reason for this, of course, is that, contrary to conditions in ordinary foundry practice where the heat from the molten steel passes out slowly through the mold, here, in the welding operation, the parts being welded act as enormous chills in the casting. They extract the heat more rapidly from the center or core than from any other point. Freezing, therefore, occurs first approximately along the axis of the parts and radiates outward from this point. The realization of this feature led, a few years ago, to a radical change in design and the elimination of the large risers, formerly thought necessary in thermit welds to feed the shrinkage of the inner portions.

It is perhaps this change in design, and the greatly reduced cost resulting from the small risers now employed, that has increased the applications of thermit welding until it is now more economical to weld almost anything in the steel mill than to substitute a new part.

To go back now to the actual applications of thermit welding in the steel mill, there are, in general, three uses for the process:

1. The repair of broken parts, which may be indicated for economic reasons such low cost as compared with replacement, or saving in time in getting the mill or machine in operation again.
2. The building up of worn parts, which in many cases replaces the material worn away with one better suited to withstand the service.
3. The manufacture of new constructions or the making of old ones in a new way.

In former years, the application of thermit welding for emergency repairs constituted almost its entire use in the steel mill. In mills where breaks occurred infrequntly, outside thermit welders were called in to take care of these emergency repairs. The value of this form of welding is admitted and thousands of cases could be recounted in which thermit welding has allowed the mill to resume operations in a fraction of the time which would be required to manufacture new parts.

As said before, however, the greatest benefits are derived from the thermit welding process in mills having separate welding departments of their own. These departments are not limited to the making of emergency repairs but undertake routine repairs of all kinds such as the salvaging of parts from the scrap pile and converting them into spares. Lists of the day to day activities of such departments reveal their important contribution to almost every branch of steel mill operation.

The introduction of such departments in steel mills was, in fact, responsible for the development of one of the newer applications of thermit welding, namely, the replacement of metal worn away in service. This has proved an exceedingly profitable undertaking for mills which have adopted it. It is possible to add in this manner a metal with wearing qualities which are far superior to those in the original piece. Rolls, pinions, spindles and many other parts must be designed for great toughness and strength. This precludes the use of steels having maximum wear resistance. It is perfectly feasible, however, in replacing the worn pods of these parts to use a thermit which will produce a steel of any desired hardness. In fact, the practice has become to select a thermit steel which is so hard as to be unmachinable; in which case the weld is made true enough to eliminate all need for machining.

New applications and changes of this kind are being brought into use almost daily. It is perfectly feasible for the steel mill to make wabbler ends of a steel offering the greatest possible wear resistance and to thermit weld such ends to the necks of ordinary rolls. In the same way, new charging peels can be kept on hand, which can be welded as required in place of broken or worn ends. Thermit steels of extreme hardness may be cast on surfaces subject to wear or in the bore of cylinders. Almost any part may, by means of welding, be designed to have different physical properties at various points. All of these factors contribute to the making of parts with greatly prolonged operating life and the corresponding elimination of expensive replacements, shut-downs and other repairs.

The process also allows for the elimination of expensive and intricate castings and the substitution of simple forgings which can be welded together. An example is that of a large steel company which is now manufacturing frogs for track work in which it uses a high grade steel casting for a center plate and to this, by means of thermit steel, welds arms of rolled steel rail. The advantages obtained consist of securing a steel of excellent wearing qualities for the point of greatest impact in the track structure while eliminating the difficulties and expense of using this steel throughout the entire piece. Many other examples could be cited but dozens of applications of this kind will readily appear to anyone familiar with manufacturing processes in steel mills.

The co-ordination of the various departments of steel mills in welding work is most important if greatest benefits are to be assured. It is, of course, not feasible to have a number of independent welding departments in one plant. Nor is it desirable to require the various mill superintendents to keep in close touch with a central welding department. This question has been solved in some mills by the organization of a reclamation department under a suitable head, who, together with the particular mill superintendent interested, is the final authority as to which broken or worn parts should be reclaimed and which should be scrapped. The mere existence of a welding department and experienced welders will not in itself effect the desired economies, and the installation of a co-ordinated reclamation department, or some suitable substitute has proved to be most important.

DISCUSSION

Discussion presented by

C. Simera, Welding Foreman, Corrigan-McKinney Steel Company, Cleveland, Ohio.

L. F. Coffin, Supt. of Mechanical Dept., Bethlehem Steel Company, Sparrows Point, Md.

J. B. Tinnon, Manager of Sales, Metal & Thermit Corporation, New York, N. Y.

J. F. Gillespie, Asst. Elec. Supt., Carnegie Steel Company, Youngstown, Ohio.

C. O. Franklin, Asst. Elec. Supt., Carnegie Steel Company, Munhall, Pa.

C. Simera: In reply to the speaker's opening remarks, that he felt he was out of place, being at a meeting of electrical engineers.

There is only one thing that I do not agree with. I understood Mr. Tinnon to say that thermit welding was rather out of place in so far as this is an electrical meeting.

Electricity was an important part of our thermit welding for several years, because we started our thermit reaction by causing a short circuit between

two carbon electrodes, instead of using ignition powder.

L. F. Coffin: I would like to ask the speaker whether he has any suggestions to offer as to how to overcome strains set up in welding new ends on main mill rolls, in cases where these rolls are high carbon or special alloy steel.

J. B. Tinnon: The usual procedure is that the strains can be eliminated by proper pre-heating. If it is a very large piece it is sometimes necessary to bring the whole piece up to some reasonable temperature in order to eliminate those strains which may be caused by the localized heat of the thermit welding. It is not an uncommon thing on pieces that are rather problematic to weld to build a furnace around the whole business and heat it, not to the same degree you heat the weld but sufficiently high so you won't have the localized stress. But as a practical matter there usually is not any trouble. It is largely a matter of practice.

C. Simera: I might add to Mr. Tinnon's remarks in connection with pre-heating a heavy welding job. Assuming that a large pinion was being welded: After mould box was in place and sand was rammed, a gas pre-heating flame is applied to the section of the pinion that was not included in the mould box, and a pan is placed at the lowest pre-heating gate.

This pre-heating is done over night. The pinion absorbs from 800 to 1200 degrees of heat and the wax is melted out and caught in the pan. About seven-eighths of the wax is reclaimed in this manner and not wasted.

Then the regular pre-heating torches are applied to the job.

J. F. Gillespie: I would like to ask Mr. Tinnon if he has any figures on the cost per weld in crane rails.

J. B. Tinnon: It costs approximately $7.00 or $8.00 to make the weld. Now if the crane rails are up in a place where you have to build an extension, that is another story. If they can be welded in long lengths on the floor and raised in position the cost is not more than about $7.00 apiece. We figure the cost on thermit welds on 100 pound rails runs around $7.00 or $8.00.

C. O. Franklin: I would like to ask the speaker how the chemical composition of the weld is controlled. That is, if you want to get a certain grade of steel for a certain job how is it obtained?

J. B. Tinnon: There are a large number of different types of thermit steel. We have manganese thermit and iron thermit. A thermit as a practical application is seldom used without some addition because it is too hot. You don't need all that heat and it is a waste of good money to buy plain thermit. It produces about 50 per cent of its weight in steel; because of your tremendous superheat you can cut that heat down by additions of, usually, steel punching. Now manifestly if you want to get a steel high in nickel, you can add nickel to the thermit. If you want a steel high in carbon, you can add carbon to the mixture. Those particular additions can't be made arbitrarily by the man in the field because of the different efficiencies of the various additions, but by long experience and test we can add those various elements to give you almost any analysis within reasonable range in the cast steel.

C. O. Franklin: Is it a matter of experience how much of the various elements to add?

J. B. Tinnon: Amount of material based on the efficiency. Some will oxidize better than others.

A. I. & S. E. E.

SPRING ENGINEERING CONFERENCE

Auspices

Combustion Engineering Division

Ohio Hotel **Youngstown, Ohio**

Wednesday Evening, April 24, 1935

Thursday (All Day), April 25, 1935

J. L. Miller, Chairman,
Assistant Chief Engineer,
Carnegie Steel Company,
Youngstown, Ohio.

F. E. Leahy, Secretary,
Fuel Engineer,
Youngstown Sheet & Tube Co.,
Youngstown, Ohio.

Tentative List of Subjects

Maintenance of Roll Neck Bearings . . . Box Annealing Furnaces . . . Improvements in Design and Operation of Open Hearth Furnaces . . . Mechanical and Metallurgical Aspects of the Rolling of Strip Steel . . . Natural Gas in Steel Plants . . . Selection of Electrical Equipment for Power Supply in Rolling Mills.

ITEMS OF INTEREST

PERSONNEL CHANGES

▲

The Alliance Machine Company, Alliance, Ohio, announces three new changes in its organization.

H. A. Fennerty, graduate of Dartmouth University, who has been associated with the company for the last six years in the engineering department, has been named the vice president and assistant treasurer, succeeding J. C. Hoot.

R. J. Harry, who has been connected with the company for the last five years and previous to that for twenty-two years with the Carnegie Steel Company at Homestead, has been advanced to the position of general manager.

R. R. Stuckey has been named the production engineer. His association with the Alliance Company has been for the last twenty years.

▲

Walter E. Hadley has been appointed general superintendent of Gary Works, the Illinois Steel Company, effective February 12, 1935, succeeding William P. Gleason, who is retiring under the pension plan in accordance with the rules of the company.

▲

Walther Mathesius has been appointed general superintendent of South Works, the Illinois Steel Company, effective February 1, 1935, succeeding George L. Danforth, Jr., resigned.

▲

Edgar C. Bain since 1928 metallurgist for the United States Steel Corporation, 71 Broadway, New York, N. Y., has been appointed assistant to vice president in charge of metallurgy and research.

▲

C. F. Hood, manager of the Worcester, Mass., district of the American Steel and Wire Company, has been appointed vice president in charge of operations with headquarters in Cleveland, Ohio, succeeding J. L. Perry, who was named president of the Tennessee Coal, Iron and Railroad Company at Birmingham, Ala.

▲

C. I. Collins, superintendent of the Cuyahoga Works of the American Steel and Wire Company, Cleveland, Ohio, has been appointed manager of the Worcester, Mass., district, succeeding C. F. Hood, who has assumed the vice president's duties in Cleveland.

▲

B. H. Gedge, assistant superintendent of the Cuyahoga Works of the American Steel and Wire Company, Cleveland, Ohio, has been appointed superintendent, succeeding C. I. Collins, who has been transferred to the Worcester, Mass., properties of the American Steel and Wire Company.

▲

Don L. Orton, sales engineer at the home office of the Clark Controller Company, Cleveland, Ohio, has been transferred to the company's Chicago district office, as sales and engineering representative.

▲

Carl Stripe has joined the sales organization of the Combustion Engineering Company, Inc., 200 Madison avenue, New York, N. Y., and will have charge of industrial stoker sales under the direction of H. S. Colby, general sales manager.

▲

H. W. Trump has been appointed to the position of district manager of the industrial division of the Timken Roller Bearing Company with headquarters at 409 Olive street, Dallas, Texas.

▲

E. L. McNamara has been appointed assistant manager of roll and steel castings division for the United Engineering and Foundry Company, with headquarters at Youngstown. He joined the United company as roll salesman in the Youngstown district in 1928.

▲

William Harry Jones, who has been identified since 1929 with the Youngstown Sheet and Tube Company, Youngstown, as assistant superintendent of the finishing department and later as assistant superintendent of the seamless tube mills, has been appointed superintendent of the seamless tube mills.

▲

John L. Campbell, since July, 1933, associated with the roll sales department of the Ohio Steel Foundry Company, Lima, Ohio, has been made manager of roll sales. He was formerly with the Hubbard division of the Continental Roll and Steel Foundry Company.

▲

T. O. Moloney, president of Moloney Electric Company, St. Louis, has been named chairman of the board of that company. J. J. Mullen, vice president, has been named president.

▲

George Gordon Crawford, former president of Jones and Laughlin Steel Corporation, has severed his connections with the company to retire to his home in Birmingham, Ala.

▲

Carl G. de Laval has been appointed sales representative of Electro Metallurgical Sales Corporation in the Pittsburgh district, effective February 1. Since 1925 Mr. de Laval has been connected with the production department of Electro Metallurgical Company at the Niagara Falls plant. His new offices will be in the Oliver Building, Pittsburgh.

▲

A. J. Wadhams, manager, development and research, The International Nickel Company, Inc., has announced the addition of David M. Curry to the development and research staff.

Mr. Curry will make his headquarters in New York and will devote his time to development work

in the non-ferrous casting field, covering the entire range of foundry operations.

▲

Directors of Blaw-Knox Co. elected Robert F. McCloskey director and vice-president in charge of operations of the plants located at Blawnox, Pa., to replace Wayne Rawley, deceased. Mr. McCloskey was previously general superintendent of the company's Blawnox shops. He has been associated with the company since 1920, starting as manager of a plant then located at Wheatland, Pa. In 1922 he was made production manager of shops at Blawnox, and in 1931 became general superintendent.

▲

The resignation of Robert Treat Paine II, for 40 years a director of the General Electric Company, has been accepted by the board of directors of the company, it has been announced by President Gerard Swope. A native of New England, Mr. Paine was elected to the board in 1894, two years after the formation of the company and in the middle of the worst year in the history of its operations. His resignation was submitted because of ill health.

WITH THE MANUFACTURERS

▲

The General Electric Vapor Lamp Company of Hoboken, N. J., has perfected a high intensity mercury vapor lamp which is particularly suitable for high bay lighting. It is a new approach to an industrial white light which is restful to the eye, which enables quick visual response even to details unknown under other commercial lighting. It promotes of continued use of the eyes without fatigue. It is a particularly efficient lamp in that it produces 14,000 lumens at a consumption of 400 watts or approximately 35 lumens per watt. It is made with a Mogul screw base for vertical mounting. The lamp has an over-all length of 13" and is designed for operation on 110 volt and 220 volt, 60 cycle circuits. It has an average life of 1500 hours.

From a technical standpoint the high intensity light is not white. It is a combination of blue light and yellow-green which produces a whiter sensation to the observer. Due to the practical absence of red rays in the light, true color values are not always rendered when red materials are involved, but this has no immediate bearing in the industrial field where fine color discrimination is rarely called for. The make-up of energy which gives the high intensity its color quality is interesting in that the major portion of energy is produced in the center of the visible spectrum (yellow-green area) to which eyes respond most efficiently. The balance of the visible energy produced by this lamp is at the blue end, which while it has little visual value does reduce the glare factor and does produce the sensation of a whiter light.

▲

The De Laval Separator Company of New York, has been awarded two additional contracts, for complete lubrication systems, by the United Engineering and Foundry Company of Pittsburgh.

The lubrication equipment for each individual system, consisting of a De Laval Centrifugal for maintaining the condition of the oil, main oil circulating pump in duplicate, maintenance cycle circulating pump in duplicate, main oil reservoir tank equipped with cooling coils, pressure tank, sight flow and sight feed fittings, as well as electric siren, will be installed in connection with the new 20½"x56"x84" cold reversing mill, two skin pass mills and 19"x 49"x56" 4-high, three stand, tandem cold strip mill, now being built for the Ford Motor Company by the United Engineering and Foundry Company of Pittsburgh.

▲

One of the first important steel mill electrification announced in 1935, includes an award to the Westinghouse Electric and Manufacturing Company for part of the electrical equipment to be installed in the McDonald Works of the Carnegie Steel Company, Youngstown, Ohio.

Large D.C. motors, which total 16,000 horsepower; motor generator sets; and control equipment comprise the bulk of the order. Delivery of the electrical equipment, which will be built in the Westinghouse East Pittsburgh Works, is scheduled to be made within the next few months. The new mill is expected to be in operation this summer.

▲

The Bantam Ball Bearing Company of South Bend, Ind., has been awarded the contract for the conical roller thrust bearings together with aligning seats on the cylinder gate hoists for the four intake towers at Boulder Dam through the general contractor, The Consolidated Steel Company of Los Angeles, Calif.

These conical roller thrust bearings, which will support the two bronze lifting nuts which engage the threaded ends of the stems to raise and lower the upper and lower cylinder gates respectively, are 14" I.D. by 24½" O.D. by 4-9/16" thick and have a load carrying capacity of 1,000,000 pounds at operating speed. These Bantam Conical Roller Thrust Bearings are of the same design as made by this company and continuously cataloged since 1906. Rollers and races are of S.A.E. 52100 high carbon chromium through hardening steel, heat treated by the Bantam special differential hardening method. Bantam one-piece lubricating type bronze cages are used for retaining the rollers.

One gate hoist will be mounted on the floor of each of the four intake towers and will be used to operate separately or simultaneously the two cylinder gates installed in each tower. The cylinder gates will be mounted one above the other in the vertical shaft of each intake tower and will be used as shut-off gates for the 30 ft. diameter penstocks extending from the base of each tower to the power plant and outlet works. The upper and lower gates will be approximately 190 feet and 340 feet, respectively, below the intake tower operating floor.

The normal operating lift of each gate will be 9 feet, but a maximum travel of 11 feet will be available to facilitate inspection and maintenance of the gates when the gate chambers are unwatered.

The hoist drive will consist of a housing containing a central gear case in which will be mounted

two entirely separate gearing systems, each driven by a separate vertical gear motor mounted on the drive housing. Each motor will be coupled, through a multiple disc, spring loaded clutch coupling, to a splined shaft on which will be mounted a mitre gear which will drive three mitre pinions each connected through flexible couplings and shafting to a worm shaft mounting in each of the three hoisting head housings. Contact circuits will be provided whereby emergency closure of the cylinder gates can be accomplished by remote control from the power house, but normally the cylinder gates will be operated from the control panels mounted on each hoist drive housing.

▲

A small, sturdy, low-priced auxiliary relay for use on A.C. or D.C. and suitable for switchboard or panel mounting is announced by Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. The type SK auxiliary relay for switchboard mounting has a molded cover or molded cover with glass front; the front connected panel mounted relay uses no cover. Both types have two independent contact circuits which may be easily adjusted for circuit-closing or circuit-opening service. For two independent opening circuits, additional material must be added to the standard relay.

Designed for continuous duty at rated voltage, the SK relay is obtainable for circuits up to 550 volts A.C. or 440 D.C. Ranges up to 250 volts can be used for intermittent duty up to approximately three times their continuous value. The relay can be supplied with a coil for any current value up to 5 amperes.

Relay is adapted for any thickness of panel material from ⅛" (steel) to 2" (slate). The molded terminals are 1⅛" long, being ample for steel-panel mounting. For thicker panels, extension terminal studs are furnished.

▲

An entirely new line of convertible squirrel cage and slip ring induction motors, offering all standard frequencies for service ranging from 110 to 220 volts, has just been announced by the Harnischfeger Corporation, West National avenue, Milwaukee, Wis.

Built in accordance with the standards adopted by the National Electrical Manufacturers' Association, the outstanding feature of these new P&H motors is their ready convertibility from open type to fan cooled, splash proof or totally enclosed construction. This is accomplished through the design of the frame, end heads and bearings to permit interchangeability in the four above mentioned types of single or multi-speed squirrel cage and slip ring motors.

▲

A new arc welding electrode which is designed for restoring worn cutting edges on tools of all kinds and which is said to permit savings of 20 to 25 per cent in tool cost is announced by The Lincoln Electric Company, Cleveland, Ohio.

This new electrode, known as "Toolweld", is the product of several years of research and of particular value to all industries using tools. By using this electrode, lathe tools, bits, milling cutters, drills, cutting and forming dies and all other tools which have become worn in service can be given a new and harder cutting edge than has heretofore been possible. Tools can be refaced an unlimited number of times with this electrode.

▲

New Bulletin No. 1010 dated January, 1935, has just been issued by the Appleton Electric Company, 1701 Wellington avenue, Chicago, Ill., manufacturers of Appleton Threaded and No-Thread Unilets, also Extension Reels for Electric Cable, covering their new line of Appleton Dead-End Circuit Breaking Plugs and Receptacles.

▲

One hundred eighty-five tons of Timken bearings will be used in the new Ford Mills, now being built by The United Engineering and Foundry Company of Pittsburgh, Pa. It is believed that this is the largest single order for steel mill anti-friction bearings ever placed.

Fifty-two bearings of the size (25½"x40½"), each weighing 4,086 pounds apiece, will be installed on the back-up roll-necks of the 21" and 46"x56" four-high hot strip mills and on the back-up roll-necks of the 18" and 46"x56" tandem cold strip mills. The loads on the back-up roll-necks of the 20½" and 56"x84" single stand reversing cold mill will be carried by four similar 30"x47" Timken bearings.

Eighty-seven different sizes of Timken bearings, ranging from 2"x3½" up to 30"x47", will go into the equipment now under construction. These bearings vary in weight from 1 pound for the smallest up to 7,640 pounds apiece for the big ones used on the single stand reversing cold mill.

▲

The new Temperature Indicator, made by Schweitzer and Conrad, Inc., Chicago, determines the operating temperatures of buses, cables, disconnects, contact clips, terminals of oil switches, transformers, etc., without shutting down equipment or disturbing any connections. Its ease of use makes it a simple matter to check for temperature rises, detect buses of insufficient capacity or unequal division of current in paralleled bus bars. Trouble can thus be averted before serious damage occurs, which is particularly essential today because of increasing loads and because maintenance and replacement of old equipment have been somewhat neglected.

▲

For use in connection with a wide variety of electrically-operated devices and machines requiring automatic timing of the "Power-on" "Power-off" periods, The Electric Controller & Mfg. Company, Station C, Cleveland, Ohio, announce the new EC&M automatic repeat process timer.

This timer is built in four standard sizes and is designed for operation on 110, 220, 440 or 550 volt circuits of any standard frequency. Operating on the principle of the time required to charge a condenser, it provides a quick, convenient means for closing an electrical circuit for a definite length of time, and then opening the circuit for a similar, or different time, as desired, and repeating this cycle of operation as long as the control push button or master is closed. Both the "Power-on" and the

"Power-off" periods are independently adjustable to give the time desired.

The "Power-on" period can be adjusted from .05 seconds minimum to .90 seconds maximum on the smallest size of timer. The "Power-off" period of this same size timer is adjustable over a similar range of time. With both the "Power-on" and "Power-off" periods set at minimum time, the timer will provide 550 operations per minute. With the largest size of timer, the "on" and "off" periods are adjustable between a range of .12 seconds minimum and 7.5 seconds maximum. Timers, of course, could be supplied with a different range of time for the "on" period than is supplied for the "off" period. For example, the "on" period could be supplied with a range of .12 seconds minimum and 7.5 seconds maximum, and the "off" period with a minimum time of .05 seconds and a maximum of .90 seconds, or other combinations that may be desired.

▲

The Delta Star Electric Company, Chicago, Illinois have prepared a new 16 page bulletin describing their improved types of "MB-139"; "VMB-139" and "FMB-139" pole top, group operated, vertical break switches for disconnecting or load break service and for manual or motor operation. These switches conform to the latest NEMA standards. Copies of the bulletin will be mailed upon request.

▲

For those responsible for the proper operation and maintenance of the electrical machinery in the plant, The Ohio Carbon Co., 12508 Berea Road, Lakewood, Ohio, has prepared a new 64 page booklet, "The Brush Phase of Motor Maintenance". The booklet, which is available on request, deals in practical non-mathematical terms with causes and effects of sparking, excessive wear, etc. of brushes, commutators, and slip-rings on direct and alternating current motors and generators, etc. Since many of such troubles are due to faults in other parts of machines the book describes briefly, and illustrates with diagrams, the conditions of sparkless running and the effects of the applied load upon them; thus simplifying the detection of troubles before they become serious. Other sections deal with brush characteristics, selection and manufacture, and suggestions for the proper methods of maintenance of brushes, commutators, and slip-rings.

▲

The Poole Foundry and Machine Company announce the appointment of the Nibling Engineering Sales Company, 309 Colonial Building, Philadelphia, Pennsylvania, as their representatives for the sale of Poole flexible couplings and speed reducers in the Philadelphia district.

▲

The Switch & Panel Division, Square D Company, Detroit, Mich., has just announced a solderless connector new design.

The connector consists of a copper cup with enclosing sides and raised lip of curved contour at the wire entrance, a specially designed hexagon nut and a stud. The hexagon nut, which can be turned by either a screwdriver or a wrench, presents smooth rounded surface to the conductor and forces the wire strands into the recess of the cup and compresses them so forcefully according to Square D engineers, that a much better contact and more secure mechanical bond is formed than by the ordinary solder lug.

The design of the connector precludes any possibility of vibration loosening the conductor, insuring a positive permanent connection. The connector can be used for either solid or stranded conductors. One outstanding feature of the new connector is the fact that it fits in the same space as a solder lug, so that it can be adapted to standard switches without the danger of exceeding electrical clearances.

▲

The Surface Combustion Corporation, Toledo, Ohio, announce a number of installations of their radiant tube sheet annealing covers, one of which is in the plants of a large steel company for annealing full finished auto body sheets.

The installation consists of a ruggedly constructed steel shell lined with high grade insulating refractory, and a base similarly constructed, both cover and base being movable. Lifting lugs are provided at the top so that no strains are set up in the casing when lifting the cover.

This cover is heated by means of Surface Combustion radiant tube elements placed in a horizontal position along the side walls and extending through the end walls. Through specially designed tube mountings, means are provided for maintaining a tight seal during the expansion and contraction of the tubes.

A plurality of heating elements is used for controlling the temperature vertically. It has been proven necessary to control the heat input in this manner.

The radiant tubes are heated with gas by means of Surface Combustion diffusion combustion, where the gas and air enter the tube at the inlet end and combustion takes place progressively along the inside of the tube, terminating at any place desired. This type of combustion produces a soft but highly radiant flame, which permits a high rate of heat transfer with a low thermal head, and an increased efficiency over premix combustion. A uniform temperature is produced free from hot spots, thus eliminating a tendency of the tubes to crack.

The air for combustion is entrained from the inlet burner by eductors placed at the outlet and powered from the air blower placed directly on the cover. Each tube is always under a negative pressure so that at no time can products of combustion enter the cover to discolor the sheets.

The operation of the cover is fully automatic. Once the burners are set, the temperature control instruments control the operation of the burners until the desired temperature is obtained, when the gas is manually shut off and cooling air is applied to accelerate cooling before removing the cover. No manual attention is required after the burners are lit until the completion of the heating cycle.

Due to the basic principles employed in its design, this cover will produce bright annealed steel sheets using DX atmosphere gas without an inner cover. It produces a sheet free from borders, and corrugations, sheets are flat when the cover is removed. Piles of sheets 58" high by 65" wide and 115" long are heated uniformly from end to end within 10° F. and with no temperature differential

top to bottom, with a fuel consumption less than 1,000,000 B.T.U.'s per ton, and a considerable saving in time of heating.

On such material where relatively high cooling rates are permissible, inner covers of light plate construction are used so that the annealing hood may be removed before completion of the cooling cycle. Long life may be expected from these inner hoods as it is arranged that DX gas is introduced to both sides of the hood, thus preventing oxidization during the heating cycle.

▲

Reading of multiple-point instrument records is greatly simplified by a new system of "numerals in colors" introduced by Leeds & Northrup Company, Philadelphia. This marking system can be specified on Micromax strip-chart recorders for 2, 3, 4 or 6 points. With each of the thermocouples, resistance thermometer bulbs or other primary elements identified on the chart by a numeral, and each numeral distinguished from the others by being printed in a contrasting color, reading of records is made easy, errors are avoided and time is saved. Colors used for printing the numerals are: black, green, red, violet, yellow and blue.

The print-wheel on these Micromax Multiple-Point Recorders has a separate inking pad for each point to be recorded.

A circular giving further details and showing a reproduction of an actual chart in all six colors will be sent on request. Address the above Company and ask for Circular No. 314-I.

▲

A small, track-type, spring-return limit switch, intended for use in making or breaking control or indicating circuits at a fixed point in the travel of a part of a machine or mechanism, has been introduced by the General Electric Company. The switch, designated as CR9440-A1A, has one normally open and one normally closed circuit. Its maximum carrying and breaking capacity is 5 amperes at 550 volts a. c. and on d. c. ranges upward from 0.4 amperes at 550 volts to 2.0 amperes at 115 volts.

The new device is operated by an 18-degree movement of its operating arm from the normal position, an overtravel of 54 degrees being possible without causing damage to the switch. A precision mechanism on the operating arm affords simple, accurate adjustment of the arm to any position around the operating shaft. This mechanism consists of a worm-and-gear arrangement in which the threads on the bolt that clamps the arm to the shaft engage with threads on the latter. Double-break silver-plated contacts, opening and closing with a sliding motion, assure good electrical connections.

The switch, with the exception of its operating arm, is enclosed in a die-cast box 4 inches high, 2-7/16 inches wide, and 1-29/32 inches deep. Installation is simple. The operating arm moves in a plane parallel to the base of the switch; hence no right-angle mounting bracket is required. At the bottom of the case, a ½-inch conduit connection is provided. Because of its spring-return feature, the switch can be mounted at any desired angle without affecting operation. A ball-protected oil hole at the front of the operating shaft simplifies lubrication. A removable aluminum cover provides convenient access to contacts and wiring studs. Contacts are easily renewable.

▲

The Electric Storage Battery Company, Philadelphia, Pa., is announcing a new publication describing the exide float meter. This is a newly developed device for determining the average voltage of a battery or a direct current circuit over a definite period of time. The meter operates on the principle of the electrolytic ampere hour meter with an accuracy of about .25% and draws a current of only .004 to .010 ampere, depending on the time between resettings.

▲

The Louis Allis Co. has just issued three new bulletins describing various motors of their manufacture.

These are bulletins No. 507 describing their line of direct current motors; bulletin No. 510 describing their totally-enclosed fan-cooled motors; and bulletin No. 514 describing single phase capacitor motors.

These bulletins are attractively printed in colors and are complete with engineering and other important data pertaining to these types of motors.

Copies of any or all of these bulletins will be sent upon request direct to The Louis Allis Co., Milwaukee, Wis.

▲

The Department of the Interior, Bureau of Reclamation, Denver, Colorado, has awarded a $108,430.00 contract to the Delta-Star Electric Co., Chicago, Illinois, for Metal-Clad Switchgear to be installed in the Boulder Dam Power House.

This switchgear will control 2300 volt power supply for all auxiliary equipment in the power house.

AMERICAN IRON AND STEEL INSTITUTE NOTES

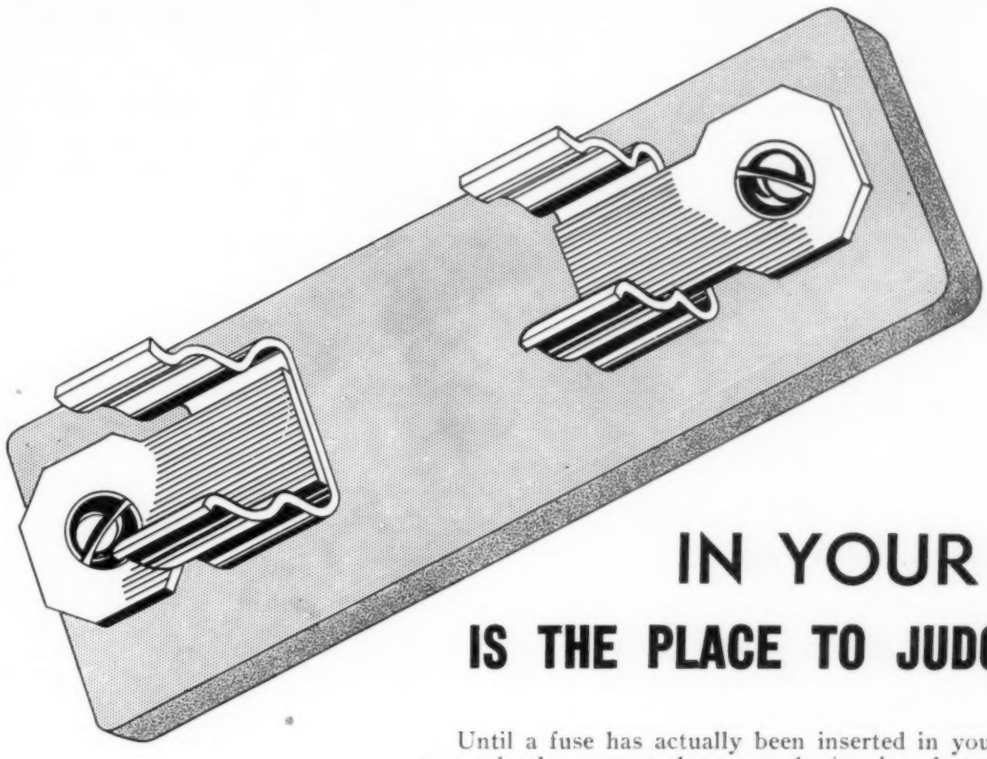
▲

Proposed legislation for a 30-hour week in industry is arousing opposition in the steel industry as well as among consumers of steel, according to reports reaching the American Iron and Steel Institute.

Steel mill employees are reported to be generally against the measure because they fear it will result in a reduction in weekly earnings or in freezing those earnings at existing levels.

Management of the steel industry is fearful that the difficulties attendant upon six-hour day operation would be unsurmountable, and would cause contraction of markets.

Consumers of steel view the measure as certain to make for substantially higher prices of steel products. It is estimated, for example, that had a 30-hour law been in effect during 1934, the added direct



IN YOUR CLIPS
IS THE PLACE TO JUDGE FUSES

Until a fuse has actually been inserted in your clips it has cost you only the amount shown on the invoice—but the moment it gets into use it costs you in proportion to the value of the service it gives you.

Value of service can best be measured in terms of the life of the fuse case and whether or not the fuse will blow needlessly.

In BUSS Super-Lag fuses definite steps have been taken to eliminate the causes of short life in fuse cases and to prevent fuses from blowing needlessly.

The simple correctness of BUSS design prevents poor contact in the fuse and means that when properly installed BUSS fuses will not char or burn up in the clips. This materially reduces fuse bills.

By reducing the chance of poor contact heating within the fuse, one of the major causes of fuses blowing needlessly is practically eliminated.

The Super-Lag Link, developed by BUSS, prevents the fuse from popping out on every harmless overload or surge. This also prevents useless shutdowns with their attendant costs of idle machinery, idle workers and the like.

Why not make your next order for BUSS Super-Lag Fuses? Watch them in service. See for yourself that they are made **to protect your equipment—and also to help keep that equipment operating.**

Write for more information if you desire it.

BUSSMANN MANUFACTURING COMPANY, 2536 W. University St., St. Louis, Mo.
A Division of the McGraw Electric Company

THE BUSS SUPER-LAG FUSE

ADVERTISING PAGES REMOVED

labor cost of making steel would have been more than one hundred million dollars. Because of the large deficits indicated for 1934, the added wage cost would necessarily have been added to prices. In addition to the direct cost, there would be an increase in cost of all materials and commodities used in the production of steel.

The increase in costs would result not only from higher wage rates but also from reduced efficiency in mill production; the necessity for four shifts in continuous operations; the impracticability of applying the six-hour day in single shift operations; increased costs in overhead, supervisory forces, and by reason of enhanced prices of raw materials and every commodity the manufacturer has to buy.

Increased steel making costs would be reflected in higher prices of automobiles, refrigerators, kitchen stoves, and all of the wide range of consumer products as well as all other types of goods made from steel.

The volume of steel orders in 1934 was only sufficient to provide three-quarters of full time employment under the existing 40-hour maximum week allowed under the code, so that the average man put in only 29.7 hours per week. Had this volume of work been shared by the greatly increased number of workers necessary to operate the mills at capacity on a 30-hour week basis, the individual employee would have average no more than twenty hours.

Steel mill employees also fear it will have the effect of further spreading or sharing of work. The steel mill worker realizes that the establishment of a six-hour day and five-day week, universally applied in all mills, factories and manufacturing establishments of every nature throughout the country, would adversely affect his interests, in common with all other classes, because it would materially increase the prices of everything he has to buy and use. The effect on him would be a substantial cut in his real wages, below levels which the steel industry holds necessary for decent American living standards.

The steel industry took the lead early in the depression in the "share-the-work" movement. Subsequently, during the first year's operation of the steel code, the industry added 73,000 employees to its payrolls and increased its outlay for wages by $95,000,000. Three wage advances were put into effect during the 12-month period.

In June, 1934, when operations were at 53 per cent of capacity, the total number of employees was 99 per cent of the 1929 average.

Any further artificial addition in steel producing costs would serve to increase the disadvantage under which the industry is now operating in comparison with foreign steel producers. Recent data show that hourly wage rates in the steel industry in the United States are from 120 to 650 per cent above the average hourly rate for similar labor in foreign countries. As a result of this, a great deal of foreign steel products is being imported into this country and sold at prices which American producers cannot meet. Imposition of the 30-hour week on the industry would increase this competitive disadvantage and act as a boomerang upon American workmen, through the loss of markets for American steel and consequent loss of jobs for steel workers.

No foreign country has reduced hours to anything like those now prevailing in the United States, and any further reduction here would still further handicap this country in world markets. In the fall of 1932, employees of blast furnaces in Great Britain, for example, were working eight hours a day seven days a week.

Since the first of the current year, mill operations have advanced sharply which means more work and higher earnings each week for each employee. Any legislation which will halt this trend toward fuller pay envelopes is not expected to find favor among steel mill employees.

COMING MEETINGS AND PAPERS

▲

PHILADELPHIA SECTION

L. F. Coffin, Chairman — **L. O. Morrow, Secretary**

Engineer's Club, 1317 Spruce Street

Dinner 6:00 P. M. — **Meeting 7:00 P. M.**

MARCH 2, 1935

"Progress of Electric Welding in the Steel Industry," by H. J. Bowles, Welding Supervisor, Bethlehem Steel Company, Bethlehem, Pa. A special invitation to attend this meeting is extended to the members of the Philadelphia Section, American Welding Society.

CHICAGO SECTION

C. J. Smith, Chairman — **A. J. Whitcomb, Secretary**

Electric Association, 20 North Wacker Drive

Dinner 6:30 P. M.

MARCH 13, 1935

"Symposium on Automatic Screw-Down Control." Papers to be presented by R. M. Bayle, Westinghouse Elec. & Mfg. Co.; W. M. Ballenger, General Electric Co.; F. J. Burd, Cutler-Hammer, Inc.; J. J. Mellon, Clark Controller Co., and D. C. Wright, Electric Controller & Mfg. Co.

BIRMINGHAM SECTION

C. R. Tinsley, Chairman — **B. Thele, Secretary**

FEBRUARY 23, 1935

"Industrial Lighting," by K. W. Mackall, Crouse-Hinds Company, Syracuse, N. Y.

PITTSBURGH SECTION

H. G. R. Bennett, Chairman — **C. H. Hunt, Secretary**

MARCH MEETING

Date and Details will be announced later.

CLEVELAND SECTION

C. Clarke Wales, Chairman — **W. W. Spanagel, Secretary**

Date and Details will be announced later.